ULTRA-SHORT WAVE AMATEUR BAND COMMUNICATION

Practical Data on the Utilization of the Three Fourths Meter and the Five Meter Bands

By James Millen

PRICE TWENTY-FIVE CENTS

DUE to the present lack of available technical and semi-technical literature on Ultra Short Wave Communication, it is felt that this reprint of a series of seven articles will make a welcome addition to our series of Manuals and Engineering Bulletins. Dealing primarily with the construction and operation of transmitting and receiving equipment for the 5 and the ¾ meter amateur bands, this material originally appeared in RADIO NEWS magazine during the latter half of 1932.

We wish to take this opportunity to thank the editor of that publication for his kindness in permitting us to republish. We also wish to acknowledge our indebtedness to QST magazine, its editors and technical staff, for their aid and assistance in connection with the preparation of the original articles, as well as in supplying the additional material employed to make this publication more accurate and complete.

James Millen

THE NATIONAL COMPANY

Malden, Mass. U. S. A.

Ultra-Short Wave
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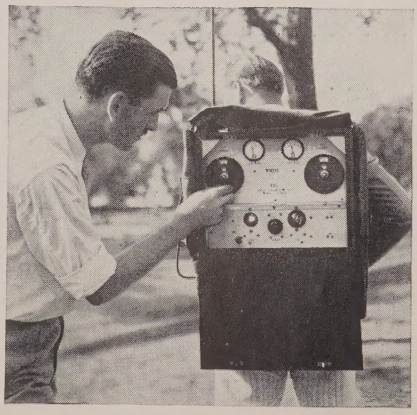
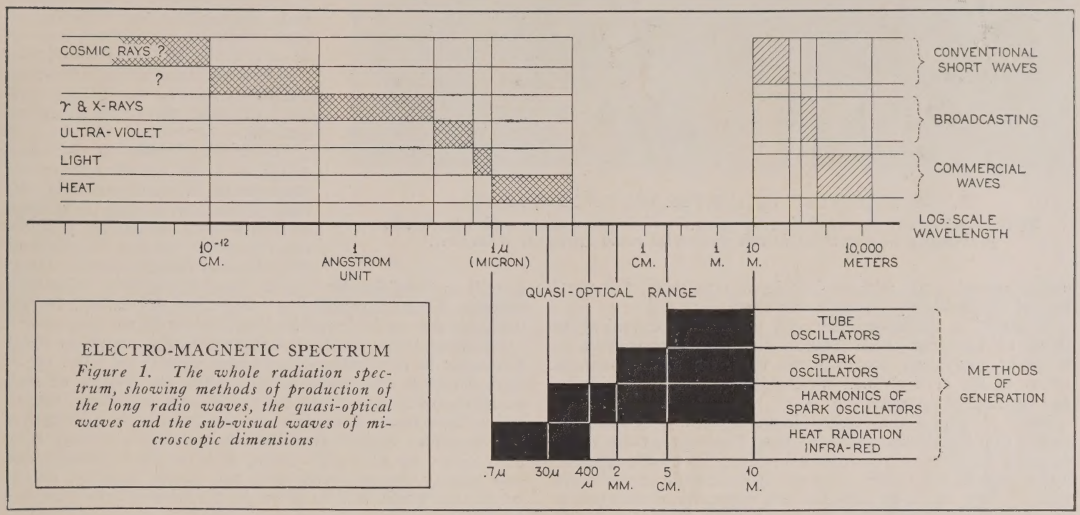
NOTE: *Throughout this series of articles will be found references to certain issues of* RADIO NEWS, *but as these articles have all been taken from that magazine and are all contained in this book, such references actually refer now to other pages in this collection of articles.*

BY MEANS of tiny short wave transmitters mounted like a knapsack on the operator's back, broadcasting is now possible on locations formerly impossible on account of the lack of communication lines. These highly portable "Below Ten Meter" midget transmitters have opened an entirely new field of broadcasting.



Professional investigators and radio amateurs have opened a new field for experimenters—the ultra short-wave range below ten meters. This is the first of a series of articles by Mr. Millen providing practical data—the real dope—on transmitters and receivers for operation on quasi-optical waves



ELECTRO-MAGNETIC SPECTRUM

Figure 1. The whole radiation spectrum, showing methods of production of the long radio waves, the quasi-optical waves and the sub-visual waves of microscopic dimensions

TRANSMISSION AND RECEPTION

BELOW TEN METERS

By James Millen

A FEW years ago, when radio broadcasting first attained its highly commercialized status, the old-time experimenter shifted his activities to the so-called short-wave field. The renewed experimental possibilities stimulated his interest, and individual pioneering was both profitable and educational for some years. Today, however, the conventional short waves are as commercialized as the broadcast frequencies, and the availability of high-grade, ready-made short-wave equipment leaves little justification for further efforts on the part of the veteran experimenter. Like Alexander of old, he seeks new worlds to conquer—and finds them in the realm of still shorter wavelengths.

Short Waves Increasing in Usage

Until several years back, two hundred meters was considered a short wave. As a matter of fact, it was thought to be the minimum wavelength practical for radio communication. Today, the bulk of the world's wireless transmission is carried on between 10 and 150 meters! As short waves became still shorter, a limit was placed again on the highest useful frequency, and it was generally conceded that wavelengths under 10 meters would be useless for signal-carrying purposes. But last year, with the opening of a new "nether region," the International Technical Consulting Committee on Radio not merely recognized the utility of still shorter wavelengths, but circumvented the possibility of another temporary limitation by including all frequencies, between 30,000 kc. and those of heat waves, in a possibly useful category. These frequencies have been designed as "quasi-optical"—wavelengths of radiated energy which behave more or less like those of light.

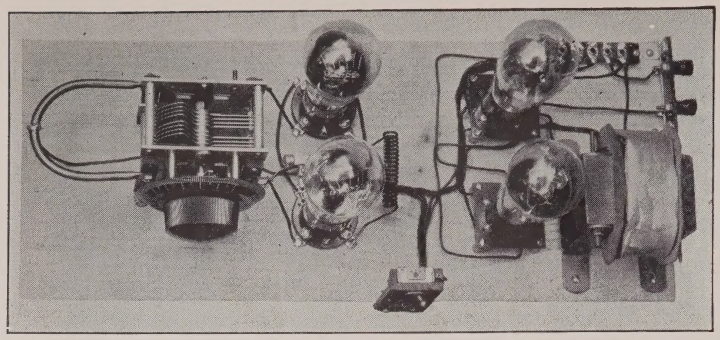
Wavelengths below 10 meters are "optical" in the sense that, like light, they follow more or less a straight line and cast definite shadows of relatively small objects. They do not bend around obstacles or readily follow the curvature of the earth as do the broadcast frequencies with which we are familiar. Also, they possess a greater power of penetration, and, therefore, are not reflected or refracted to any great extent by the Kennelly-Heaviside layer, and communication is almost limited to points between which it would be possible to transmit light under perfect weather conditions. However, unlike light, these short waves are quite independent of weather and will readily penetrate clouds and fog. This, too, is a familiar optical phenomenon, as the general tendency toward diffusion increases with the frequency. For instance, the sky appears blue due partly to the fact that the blue light of high frequency in the visible spectrum is diffused in the atmosphere.

When an arc of incandescent lamp is lighted, only a small amount of the power is radiated as light. Most of it is dissipated as heat that cannot be used for communication purposes. However, with the very short radio waves, a considerably greater portion of the power input is radiated, and low powers can be used for consistent communication purposes. The shorter radio waves are also fairly amenable to reflection by optical methods, thus greatly increasing the effectiveness of low powers. Communication has been carried on across the English Channel on a wavelength of a few centimeters with a power that would barely light a flashlight bulb!

10-Meter Tests in Berlin

Nature finds it difficult to generate these quasi-optical frequences and, therefore, reception on these low waves is remarkably free from static and similar noises. In 10-meter tests in Berlin the noise level was only one-tenth that experienced on regular broadcast frequencies.

Due to the fact that there is no varying reflection from the Kennelly-Heaviside layer, reception being the result of a



RADIO TELEPHONY SET-UP FOR USE ON FIVE METERS

Figure 5. The two pentode tubes shown at the right are used to modulate the two push-pull oscillator tubes in this five-meter radio telephone transmitter

direct ground wave without interference patterns, the usual sort of fading is conspicuous by its absence.

While it is mathematically and physically convenient to think of broadcast and conventional short wavelengths in terms of equivalent frequency, we shall, for similar reasons, revert to the old-fashioned wavelength system in considering quasi-optical phenomena.

Figure 1 shows the entire electromagnetic spectrum, arranged in a logarithmic extension from the longest radio waves down to the shortest sub-optical manifestations. Wavelengths within various ranges are conveniently handled by a variety of units. Very short wavelengths are generally considered in Angstrom units, which are one ten-thousandth of a millionth of a meter long. The micron is one millionth of a meter or 10,000 Angstrom units. The usual metric units, the millimeter and centimeter, are next in convenience. The entire spectrum is most readily handled mathematically, by negative powers of 10 times the centimeter.

Generating Quasi-Optical Waves

Figure 1 also indicates the method by which the quasi-optical frequencies are generated. It is of particular scientific interest to note the overlapping of the two possible systems for generating wavelengths between 30 and 400 microns. This was, in effect, a no-man's land of science, and the fact that the phenomenon it covers can be produced either by electrical or optical methods is additional evidence of the continuous nature of electromagnetic manifestations.

We are, for the time being, interested in the tube oscillating systems. While shorter wavelengths can be obtained by means of the spark apparatus, they are only of laboratory significance and so far give no indication of an ultimate practical application. However, the utility of the wavelengths readily generated by the tube oscillators has been demonstrated beyond a question of doubt.

The therapeutic possibilities of such wavelengths are receiving serious medical consideration, and the March, 1932, issue of RADIO NEWS contains an illuminating article by Dr. Irving Saxl on the biological effects of these waves on living organisms.

The factors influencing the application of these wavelengths to the purposes of intercommunication are indicated in our opening paragraphs, and have been adequately corroborated in many working installations. The National Broadcasting Company, as well as the Columbia System, has been experimenting with portable 5-meter transmitters which may be carried by announcers and used for mobile broadcasting of sporting events.

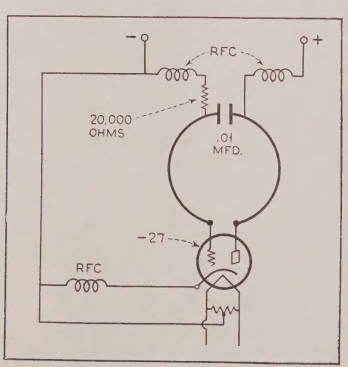
Experimental work of a semi-commercial nature is being conducted in the Empire State tower, New York City, on an ultra-short-wave television system. The possibilities of such an arrangement are considered particularly promising, due to certain simplicities in modulation associated with quasi-optical transmission. Signals from this experimental station have been picked up fifty miles away, with excellent intensity and tone quality, on an inexpensive and simple receiver, details concerning which will be given in a following article in this series.

A strictly commercial application of the quasi-optical waves is responsible for the consistent telephonic communication between various islands in the Hawaiian group over distances as great as 200 miles. While the transmitters and receivers are installed well up on the mountains, they are by no means within optical range of each other, and advantage is taken of the slight refractive effect to which reference has already been made. Reception is clear and staticless and is "piped" down to the usual insular telephone systems.

Tube Oscillators

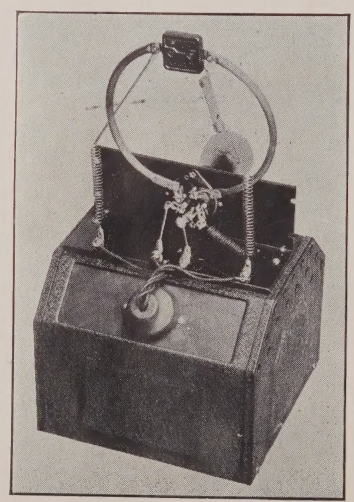
The tube oscillators of practical utility in the generation of quasi-optical wavelengths fall into three categories—the familiar regenerative oscillating arrangement, the Barkhausen-Kurz systems and the magnetron.

These systems will here be considered in the order indicated. Figure 2 shows a short-wave transmitter, complete with power supply, designed to operate at 2



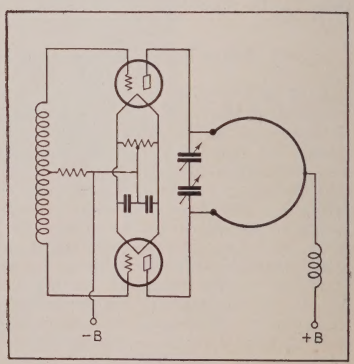
SIMPLE CIRCUIT

Figure 3. The schematic diagram for the complete two-meter transmitter shown in Figure 2 at right



FOR TWO METERS

Figure 2. Photograph of a complete transmitter for work on a two-meter wavelength complete with power supply, oscillator tube and other essentials

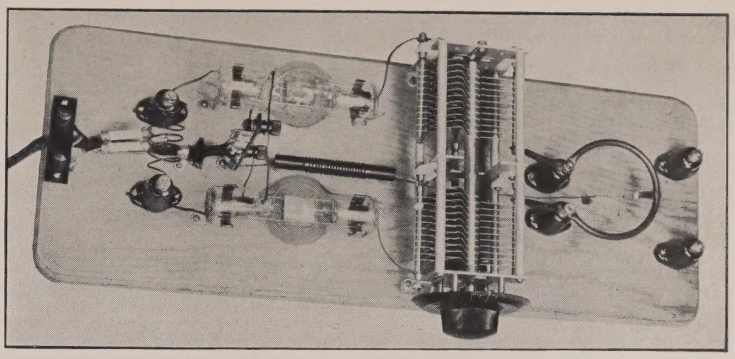


PUSH-PULL CIRCUIT

Figure 4. Diagram of the push-pull circuit using standard tubes in transmitters shown in Figures 5 and 6

meters. The tube used is a standard –27 type and the base has *not* been removed. The wiring diagram is shown in Figure 3. It is interesting to note, in conjunction with this transmitter, that the shunting of the condenser directly across grid and plate did not reduce the wavelength appreciably. However, the energy output at 2 meters was increased 75 percent by the substitution of low-loss insulation "R-39" for the standard bakelite tube base and condenser molding, along with an isolantite socket in place of the bakelite. This indicates the importance of low-loss design in ultra-high-frequency work.

In the range of from 4 to 10 meters almost any of the standard triodes can be used successfully, especially in the push-pull circuit shown in Figure 4. Figure 5 shows a 5-meter radio-telephone transmitter employing –10 type tubes with pentode modulators. Where higher power is required, the 852 is probably the most satisfactory, and Figure 6 shows a highly effective 5-meter transmitter employing two of these tubes in a push-pull arrangement. For transmission below 2 meters, special tubes and circuits become necessary. The usual triode, with base removed, is still effective between 1 and 2 meters, but its power output falls off rapidly as the wavelength is decreased. For still shorter wavelengths the Barkhausen-Kurz and magnetron oscillators are more effective.



POWERFUL FIVE-METER C.W. TRANSMITTER

Figure 6. This layout contains the same oscillator circuit as shown in Figure 5, but using the more powerful 852 type tube for higher output

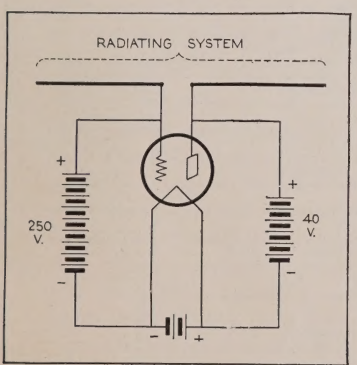
The Barkhausen-Kurz Oscillator

The frequency at which the regenerative oscillators, heretofore considered, have oscillated, has been determined by the inductance and capacity of the circuit elements in the usual way. However, as the wavelength becomes shorter and shorter, the time required for the electrons to perform their customary transits approaches the "period" of the circuit, making it difficult or impossible to maintain the phase relationships essential to stable oscillation. The circuits previously described have also functioned with the conventional distribution of potentials among cathode, grid and anode.

The Barkhausen-Kurz oscillators function as a result of the natural tendency of an electronic stream to oscillate about an axis of potential, at a period determined by the velocity and distance traveled—the effect that contributes to the inefficiency of regenerative oscillators at centimetric waves. The Barkhausen-Kurz circuits upset not only our conventional theory of how oscillators work, but likewise our practice of maintaining the anode at a positive potential in respect to the cathode and grid. In the B-K circuits, the grid is highly positive to both cathode and plate, and the anode may often be negative in respect to the filament. A typical Barkhausen-Kurz circuit is shown in Figure 7.

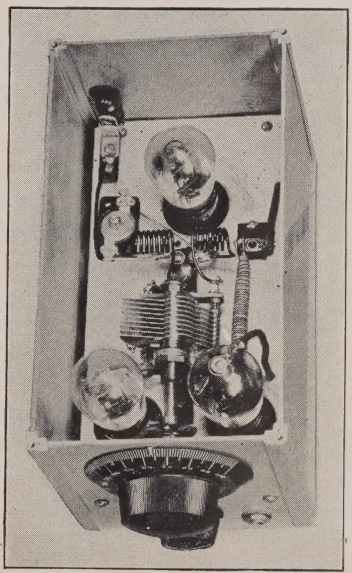
Without recourse to higher technical considerations, the functioning of such a circuit may be explained as follows: Electrons leaving the hot filament are attracted to the grid by the high positive potential. Many of them stick to the grid, while others, impelled by their momentum, speed through the meshes. The escaped electrons are rapidly de-accelerated, particularly if the plate is negatively charged with respect to the grid, and are again attracted to the grid. Once more some electrons stop at the grid while others continue through, to reverse again with the new electrons leaving the filament, recommencing the cycle. The time required for a complete oscillation is obviously governed by the distance the electrons travel, which is partially determined by the spacing of the tube elements and by the velocity of the electrons which is a function of the potential at which the tube is operated. It is therefore apparent that the wavelength of such a circuit may be altogether independent of the values of inductance and capacity and can be varied over quite a range merely by changing the grid and plate voltages.

However, it has been discovered that the output of the Barkhausen-Kurz oscillator is increased considerably when the natural period of the circuit, as determined by L and C, corresponds to the relaxation (*Continued on page 6*)



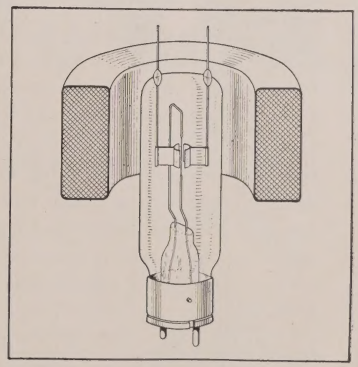
BARKHAUSEN-KURZ CIRCUIT

Figure 7. This is the fundamental B-K hookup for the high-frequency oscillator of extreme simplicity for ultra short waves



ULTRA SHORT-WAVE RECEIVER

Figure 9. A view of a five-meter receiving set with the top shield removed to show simple layout



THE MAGNETRON OSCILLATOR

Figure 8. In this sketch of the magnetron oscillator tube a field coil is shown, partly cut away, for controlling ultra high-frequency oscillation

period (the time required for an electron to leave and return to the grid) of the tube.

The Magnetron Oscillator

The magnetron oscillator may be described as a Barkhausen-Kurz tube operating under the influence of a magnetic field. The field is produced by a coil surrounding the tube, as suggested in the drawing, Figure 8. The efficiency of the tube is increased considerably as a critical value of field strength is approached, thus making possible relatively large outputs at wavelengths as short as 3 centimeters!

Full constructional details on Barkhausen-Kurz and magnetron oscillators will be given in future articles in this series and will feature a ¾-meter amateur-band, radio-telephone transmitter.

Antennas and Wavemeters

The antenna systems employed on ultra-short waves are simple examples of the "dipole" or Lecher wire type. As the dimensions seldom exceed a single wavelength, they are very small and instantly portable. The use of Lecher wires makes it possible to measure the radiated wave with great accuracy, even on the shortest practical wave, while between 1 and 10 meters, modifications of conventional wavemeters provide satisfactory methods of wavelength determination.

Ultra-Short-Wave Receivers

Where the field strength is adequate, the crystal detector provides a simple and effective receiving system. A tube may also be used, often in a slight variation of the transmitting circuit. At the present time radio-frequency amplification is almost impossible at quasi-optical wavelengths, but it is logical to presume that special tubes, suitable for this purpose, will be developed in the not distant future. Simple regenerative circuits may be used, with a distinct gain in sensitivity, but superheterodynes will not be practical until extremely stable ultra-short-wave oscillators are developed. However, the super-regenerative circuits offer distinct possibilities, as the gain can be increased in this system to an extent not achieved by any other method of reception. Constructional details on highly efficient receivers will be given in succeeding articles. Such a receiver is shown in the photograph, Figure 9.

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SOME RECEIVER AND CONVERTER DESIGNS FOR USE

BELOW TEN METERS

In this second article of this series the author shows how the problems of 5-meter reception can be solved by the design of special parts and circuits. The third article will describe the complete constructional details of an ultra-short-wave superheterodyne

By James Millen*

FEW short-wave receivers now available function below fifteen or fourteen meters. However, with the present amateur, experimental and commercial activity in the quasi-optical region below ten meters, there is a demand by the average experimenter for receivers that will perform satisfactorily at least as low as three meters.

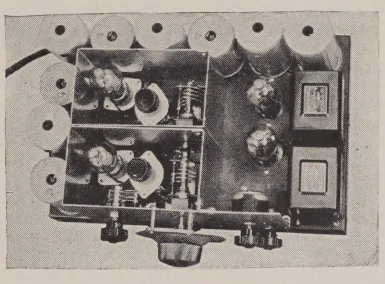
The natural question is, how may such a receiver be constructed—what new technique and operating finesse will be required of the experimenter?

Primary among the general problems is the matter of insulation losses. The short-wave experimenter has long been familiar with the dielectric phenomena associated with high-frequency work and will readily anticipate the importance of insulation design in the quasi-optical range. In the course of laboratory experiments with a two-meter transmitter, it was possible to increase the power output 75 percent by the substitution of low-loss "R-39" insulation for bakelite in the tube base and condenser construction.

In addition to the "R-39" products, a special Isolantite has been developed for ultra-short-wave apparatus. Rigidity is another essential, and the results of these two considerations are embodied in an entirely new line of sockets, coil forms and variable condensers. These last are characterized by a minimum of high-grade insulation, thick, rugged plates with smooth rounded edges, and compact construction to facilitate the use of short low-impedance leads. (Figure 1.)

Tubes admirably suited to the requirements of reception below ten meters are now available and are represented by the −56, −57 and −58 series. These new tubes have extremely low inter-electrode capacities, high plate impedances, high amplification factors and mutual conductances, which make possible the construction of a receiver providing excellent performance on wavelengths even shorter than three meters.

The simplest type of receiver for use on this band is the straight detector circuit, backed up with a generous amount of audio-frequency amplification, made practical by the low noise level of the detector output. Such an arrangement will give good reception within 25 miles or so of the new N.B.C. Empire State Tower voice and television transmitter in New York City, and is shown diagrammatically in Figure 2. Figure 3 shows the finished receiver and Figure 4 a high-quality, high-gain audio-frequency channel. The amplifier comprises three transformer-coupled stages employing −27 tubes, completely a.c.-operated.



3-10 METER SUPER

Figure 6. The completed super covering 70,000 kc. between 10 and 3 meters with five sets of coils

Super-Regenerative Receiver

Super-regenerative receivers have been particularly successful on ultra-short waves, due to the simplicity of design and the signal intensity that can be built up with a minimum of tubes. Old-timers will recall that the original Armstrong super-regenerative

*The National Company, Inc.

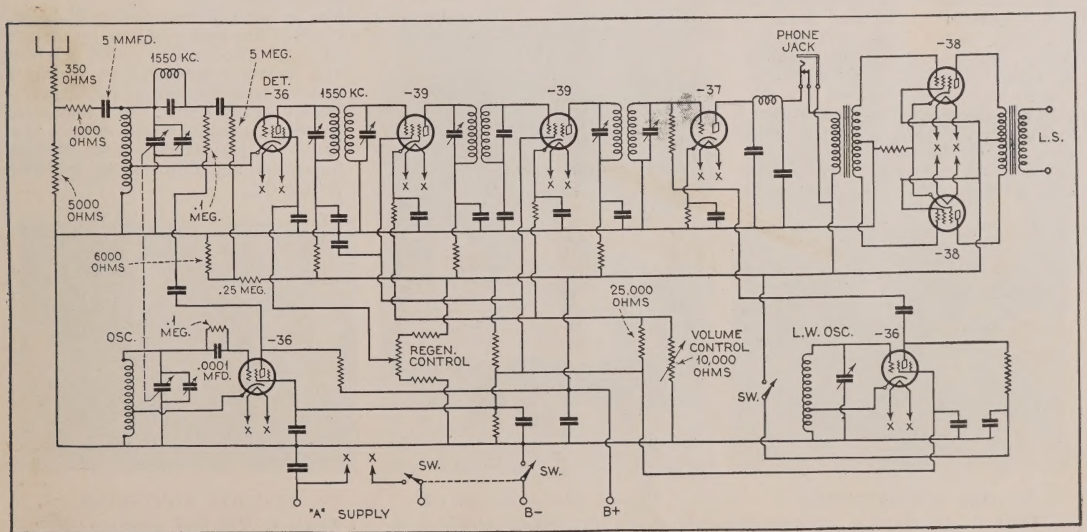


FIGURE 5. ULTRA-SHORT-WAVE SUPER CIRCUIT AS USED IN ORIGINAL EXPERIMENTAL MODEL

See page 11 for final commercial diagram

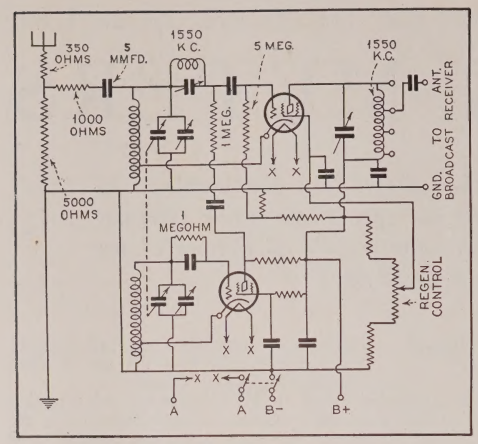


DIAGRAM OF CONVERTER

Figure 10. The ultra-short-wave converter circuit as it emerged from the laboratory

CONVERTER WITH AUTO RADIO SET

Figure 8. Testing an improved experimental converter in conjunction with an automobile radio

circuit was a single-tube receiver, which, oscillating somewhere above audibility, applied an alternating grid potential—the "suppressor frequency"—so that a high degree of regeneration could be secured at the desired radio frequency without spilling over. The principal modification for quasi-optical work lies in the use of a separate generator for the suppressor frequency.

Ross Hull has developed an entirely practical super-regenerative receiver, employing three tubes—detector, oscillator-suppressor and pentode power amplifier—which is widely used by amateurs working on th 5-meter 'phone band. The detector is somewhat unique in that it employs series tuning, rather than the conventional parallel arrangement, thus permitting the use of a rather large tuning capacitor without channel crowding. It is important, in designing a circuit of this order, that the tuning condenser have tapered plates—the straight-frequency-line type—so as still further to reduce the effect of station crowding.

A high noise or hiss level, between stations, is characteristic of the super-regenerator and is caused by the suppressor grid swing. This disadvantage, however, is somewhat compensated by the fact that the hiss is considerably lowered at station resonance.

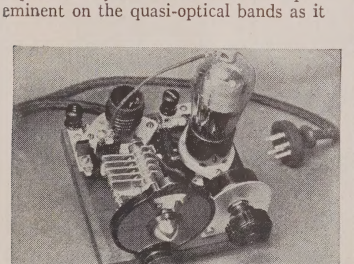
The super-regenerative receiver is inherently broad, a trait that is convenient rather than detrimental at the present time, but which, in the future days of even ultra-short-wave congestion, will doubtless mitigate against the general use of this receiving system.

With the rapid development of stable ultra-high-frequency oscillating systems, such as the Dow or electronic-coupling circuits, there is little doubt that the superheterodyne will become as pre-eminent on the quasi-optical bands as it has on practically all lower frequencies. Apart from the sensitivity of such a receiver (laboratory experiments prove that it will bring in stations 50 or more miles distant that are inaudible on the best super-regenerators), the superheterodyne provides the added advantage of efficient elasticity. With five sets of coils, plugging into a properly designed super, it is possible to cover the enormous frequency range of 70,000 kilocycles, between ten and three meters!

Another point in favor of the ultra-short-wave "super" is that the low signal-to-noise ratio characteristic, working to the disadvantage of the super between 10 and 100 meters, reverses itself on still shorter wavelengths. In order to improve the signal-to-noise ratio it is essential that the conversion loss in the first detector be extremely low—one of the main points of modern superheterodyne superiority over the earlier types. In the ultra-high-frequency super to be described in the next issue of Radio News, a regenerative first detector, used in conjunction with a scientifically engineered mixer circuit, results not only in the elimination of this conversion loss but in actual *signal amplification!*

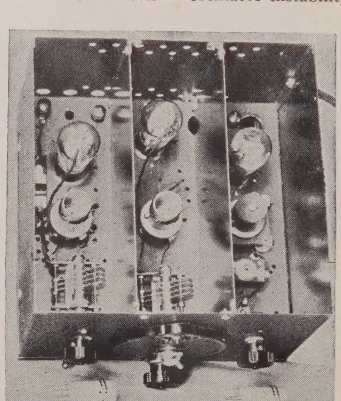
The circuit, Figure 5, has been so designed that regeneration is practically constant over the entire tuning range, removing the necessity for regeneration control adjustment except for the reception of very weak signals.

The principal problem in ultra-short-wave super design, oscillator instability or "drift," has been overcome by the use of an electric-coupling system whereby the frequency determination circuit is isolated from the load or oscillator-frequency supply circuit. It is impossible to couple a second circuit directly to a self-oscillating circuit, without resulting vagrancies and drift to the oscillator frequency.



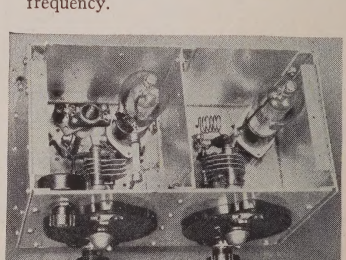
ONE-TUBE RECEIVER

Figure 3. Quasi-optical reception in its most simple form—single-tube, straight detector



ULTRA-S.-W. CONVERTER

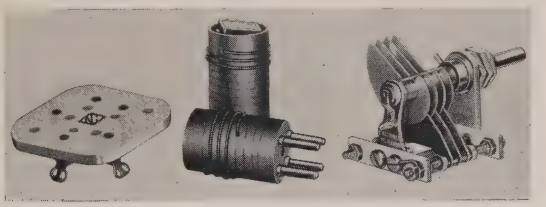
Figure 7. Preliminary design of an ultra high-frequency converter—employing an i.f. stage



FINISHED CONVERTER

Figure 9. The final converter. Electronic coupling, two tubes, low cost and compact appearance

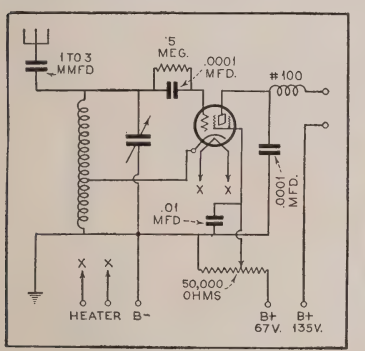
This may be due to one or more of several causes. The interaction of the two circuits is such in a superheterodyne that a signal variation may cause a change in the oscillator load condition, and at the same time a change in the oscillator plate voltage, either variation being sufficient to shift the oscillator frequency. A less immediate and secondary drift may be occasioned by temperature variations in the elements of the oscillator tube, due to a primary change in the load. The oscillator frequency being definitely a function of heaters and plate voltages, frequency drift will also be effected by the inevitable fluctuation in line potential.



ULTRA-SHORT-WAVE PARTS

Figure 1. Socket, coils and tuning condenser specially designed for ultra-short-wave reception

These effects can be reduce to practical elimination by the use of electronic coupling between the actual oscillating circuit and the circuit supplying the oscillator frequency to the first detector or mixing tube. In Figure 5, both the screen-grid and the plate of the oscillator tube function as anodes, the screen-grid, the control grid and the cathode being the elements of a triode oscillating system. These oscillations cause a periodic or pulsating flow of plate current (plate or second anode to cathode) which is used to set up an oscillatory current in an altogether independent load or work circuit. Thus there is no capacitative, inductive or any interactive coupling between the frequency-determining circuit and



ONE-TUBE CIRCUIT

Figure 2. Circuit diagram of a simple ultra-short-wave receiver—to be followed by audio-frequency amplification

the rest of the receiver. The frequency of the oscillator is also independent of any reasonable fluctuation in plate or heater voltage caused by line variations, due to the fact that such changes set up counteractive effects between the two anodes.

The general effect is comparable to the increased frequency stability secured by using a buffer stage in a master-oscillator circuit. An idea of the stability attained in an electronic-coupled oscillator will be assimilated when it is mentioned that such oscillators operating in transmitting circuits at 24,000 kc., or 12.5 meters, have been declared the equal of crystal-controlled systems.

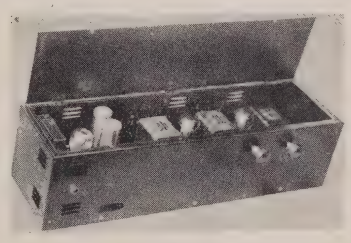
The completed superheterodyne is shown in the photograph in Figure 6.

An Ultra-Short-Wave Converter

A quasi-optical converter is recommended to the experimenter who does not care to inaugurate his 5-meter tests with the superheterodyne and yet desires something more sensitive than the simple detector arrangement and more flexible than the super-regenerator. Such a device is highly satisfactory and can be used in front of either a standard broadcast or a conventional short-wave receiver. Photographs Figures 7, 8 and 9 show the laboratory evolution of a very successful ultra-short-wave converter.

Our original converter experiments employed an odd circuit in which an effort was made to utilize a multi-element tube in a semi-autodyne arrangement. While experiments with this converter indicated several interesting possibilities, it was abandoned for the three-tube unit shown in Figure 7, employing a –36 tube as a plate-rectification first detector, a similar tube as an electronic-coupled oscillator and a –37 in an i.f. stage tuned to 1550 kc. Following painstaking experimentation, it was discovered that by the use of grid rectification, in conjunction with a suitable i.f. trap circuit, with the correct degree of oscillator coupling, the sensitivity was so increased as to eliminate the justification for the intermediate-frequency stage. (Figure 8 and 9.)

The trap circuit favors the intermediate



AUDIO AMPLIFIER FOR ONE-TUBE SET

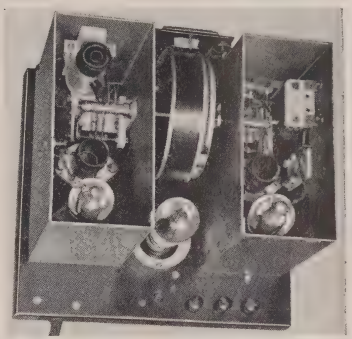
Figure 4. A high-quality, high-gain audio channel for use with the single-tube ultra-short-wave receiver

frequency, resulting in considerable amplification—the output, in effect, being impedance-coupled to the receiver. The coil and condenser must be of low-loss design, Litz wire being almost essential. The L/C ratio should be high, the condenser having a capacity in the neighborhood of 30 mmf. Since the trap is connected to the high r.f. side of the signal circuit, the capacity to ground is minimized by mounting the trap close to the grid connection of the tube.

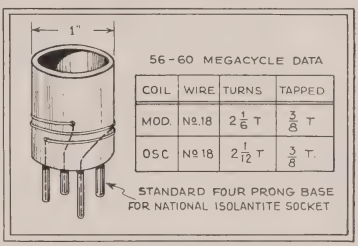
Values of grid condenser and leak are not critical, but the potential to which the grid leak is returned must be between 8 and 14 volts for highest efficiency.

As this type of detector operates with the grid slightly positive, very loose oscillator coupling is employed to reduce the possibility of overloading the grid circuit. The coupling condenser has a value of between 3 and 4 mmf. and other coupling resistor 20,000 ohms. Obviously, unless adequate shielding is used, the stray capacity between the circuits will provide sufficient but uncontrolled coupling, and if the shielding is unsatisfactory it is possible that the detector will be overloaded with no direct connection to the oscillator.

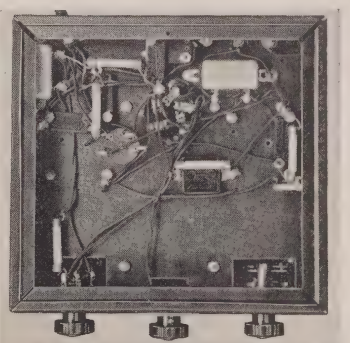
ADDITIONAL VIEWS OF 56 MEGACYCLE CONVERTER AS DESCRIBED IN DETAIL ON NEXT PAGE



Rear top view of U. S. W. converter with shield covers removed


1"
56-60 MEGACYCLE DATA
COIL | WIRE | TURNS | TAPPED
MOD. | №18 | 2 1/6 T | 3/8 T
OSC | №18 | 2 1/12 T | 3/8 T
STANDARD FOUR PRONG BASE FOR NATIONAL ISOLANTITE SOCKET

Winding data for the coils used in the 5-meter band converter



Bottom view and relatively simple wiring of 5-meter converter

OPENING UP THE QUASI-OPTICAL

56-Megacycle Amateur Band

WITH AN ULTRA-HIGH FREQUENCY CONVERTER

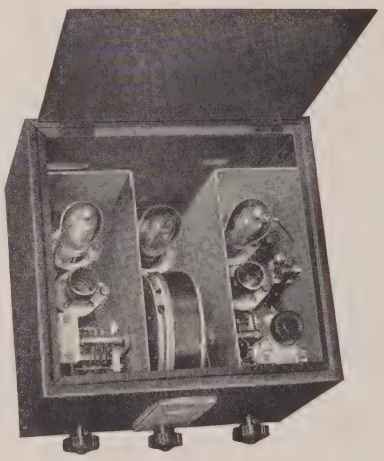
AS THE cost of a complete ultra-high frequency superheterodyne receiver is in many instances prohibitive to the average amateur or experimenter, a special converter has been developed which when used with a good broadcast receiver will form a combination having most of the advantages of the new National type HFR complete receiver. This converter is illustrated in the accompanying photograph and diagram. The special coils, sockets and tuning condensers are shown in detail in Fig. 1, page 9. On page 9 will also be found table of coil winding data. The condenser capacity is so selected as to spread the 56–60 MC amateur band over approximately 100 dial division so as to give full band spread. In addition to comprising an electron coupled oscillator and ultra-high frequency detector, there is also built into the converter a combination I.F. and coupling stage so that the converter may be used with most any type of broadcast receiver regardless of the contents of the complete circuit and regardless of the R.F. amplification or gain as the I.F. stage in the converter supplies all the necessary amplification. In constructing an ultra-high frequency converter of this type it is absolutely essential that the insulation used in the condensers, sockets and coil forms be of special low loss material suited for ultra-high frequency work, such as NATIONAL R-39 or NATIONAL Isolantite. This is particularly true of the coil forms which are molded of the extremely low loss R-39.

Tubes

The design of this unit is such that it may be operated with either the 6v. DC heater type tubes or 2½v. AC tubes. In the first case, 2—236s are employed for detector and oscillator and a 237 for the output coupling tube. For AC operation, the corresponding tubes are 2—224s and one 227. 235 tubes may be substituted for the 224s if desired. A certain amount of care must be exercised in the selection of tubes or trouble will be experienced from microphonics or noise resulting from leakage between heater and cathode. This latter trouble appears as a loud grating or scratchy hum. As a general rule, tubes of recognized quality having standard characteristics will prove entirely satisfactory. No special matching is required since ample provision for balancing tube capacities, etc., is incorporated in the various circuits.

Antenna

The antenna requirements are not in any way critical, although as a general rule a single wire as high as possible will give best results. The directional effects of various types of antennae are often very pronounced at high frequencies so that the use of a vertical antenna located well away from any surrounding objects usually gives best results. The length may be between five and fifty feet overall. A longer wire is not recommended as it tends to increase the noise to signal ratio.



The 56-Megacycle Amateur Band Ultra Short Wave Converter

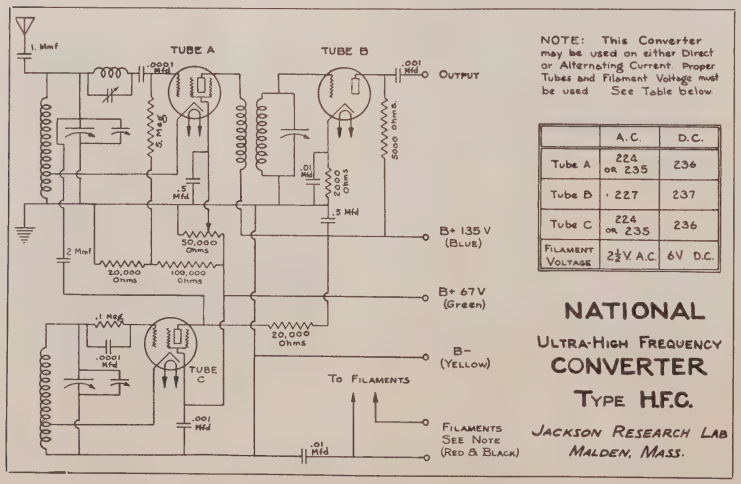
Power Supply

The filament or "A" supply may be either a 6v. storage battery or 2½v. transformer depending upon the type of operation desired. In most installations, no connection between the storage battery and B— is required, although under certain conditions it may be advisable to ground one side. When a 2½v. filament transformer is employed, the center of the winding should be grounded by means of a tap on the secondary or a center tapped resistor having a total resistance of 10 or 20 ohms. The B supply may consist of either B batteries or a B eliminator, the batteries being preferable where fluctuating line voltages are encountered. The voltages are not critical and may be between 67 and 75 for the screen circuits and 135 to 180v. for the plate circuits. Reference to the circuit diagram will show that the B batteries are subjected to a certain amount of current drain when the converter is not in use. The B— should, therefore, be disconnected during idle periods.

Intermediate Frequency Amplifier

The circuit of the type HFC converter is such that almost any broadcast receiver will be quite satisfactory for use as the I.F. and audio amplifier. For best results, the receiver should have a fair degree of sensitivity and should be stable. If the receiver has a tendency to oscillate, it will be somewhat emphasized when the converter is connected, which may make it impossible to fully advance the volume control without causing overall oscillation. Extreme sensitivity and selectivity are not required, since the converter employs a high gain I.F. stage and is in itself quite selective. As a matter of fact, the use of an extremely selective broadcast receiver is something of a disadvantage especially when hunting for signals or when receiving signals having a large degree of frequency modulation. The receiver should be capable of tuning to a frequency of 1550 K.C., the frequency at which the converter is designed to operate. If it so happens that a powerful station is operating on this frequency, the receiver should be detuned sufficiently to avoid the possibility of interference. Detuning as much as 30 or 40 K.C. has no appreciable effect upon the ganging.

(*Continued on page* 29)



OPENING UP THE QUASI-OPTICAL WAVES

BELOW TEN METERS

WITH A 3-10 METER SUPERHETERODYNE

By **James Millen***

THE evolution of ultra-short-wave receiving systems toward the logical development of a highly efficient superheterodyne was considered in our second article. And now a new and different superheterodyne receiver emerges from the laboratory in the thoroughly practical and advanced design diagrammed in Figure 1. The receiver is best described by a detailed consideration of the circuit.

Casual inspection of Figure 1 will indicate several points of conventionality—first detector or mixing tube inputting directly from the antenna coil, followed with two intermediate frequency tubes and the second detector (demodulator) which outputs directly to push-pull pentodes. However, variations from the usual procedure will be found in the electronic coupling arrangement between the oscillator and first detector circuits, the regenerative first detector, the single-tuned circuits in the intermediate-frequency amplifier and in the beat-frequency oscillator coupled to the second detector tube. Further analysis will bring to light more subtle originalities in the operating biases and in the working out of circuit details. The antenna-coupling system has been designed in a successful effort to eliminate dead spots in the tuning range, which are particularly noticeable when a regenerative circuit is coupled directly to the antenna. Such points exist when the natural period of the antenna or one of its harmonics, falls within the tuning range—an inevitable condition in the case of an ultra-high-frequency receiver. It was found that the effects of harmonics could be eliminated by the inclusion of a very small capacitor, C1 (1 mmfd.), in series with the antenna. Due to the fact that the first detector circuit is of very high impedance, having negligible losses and efficient regeneration, the minimizing of the series antenna capacity entails no appreciable signal attenuation. Also, the antenna capacity has no effect on the tuning control, because the total shunt capacity must always be less than the value of the series condenser.

It should be noted, however, that this arrangement is only effective in eliminating dead spots caused by harmonics of the antenna period, other than the fundamental, and it is necessary therefore that the aerial does not resonate in the operating frequency band. Almost any aerial over 15 to 20 feet long will be satisfactory.

While it is recommended that the antenna and oscillator coils, respectively L1 and L2, be purchased ready wound, the data in Table 1 are given for the benefit of amateurs possessing the experimental facilities and patience requisite for the fabrication of the correct inductors. All coils are wound with number 18 enameled wire on R-39 low-loss forms, 1 inch in diameter and threaded 8 turns to the inch. The coils plug into the special four-prong sockets designed for ultra-short-wave

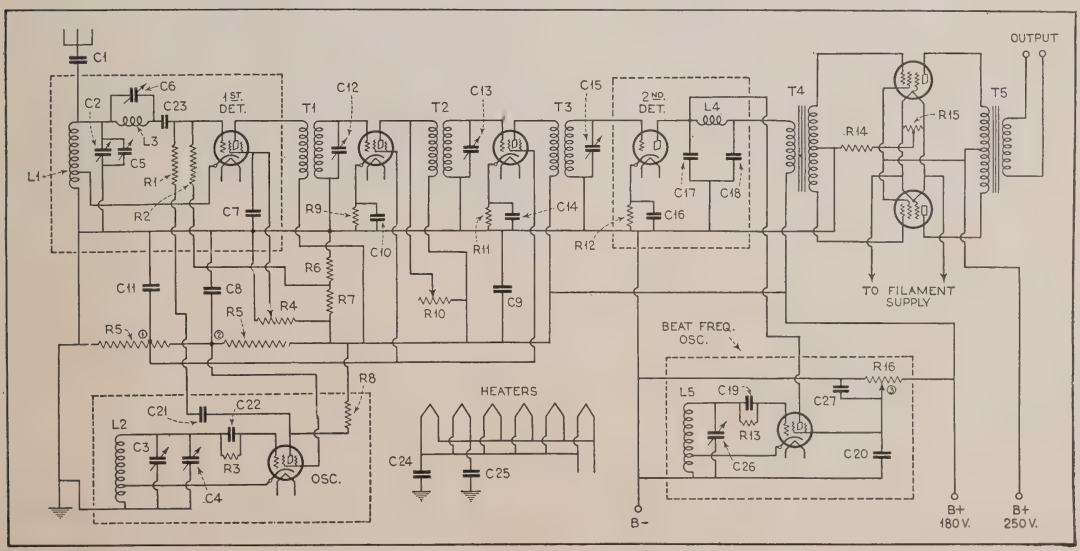
Increased Selectivity and Range

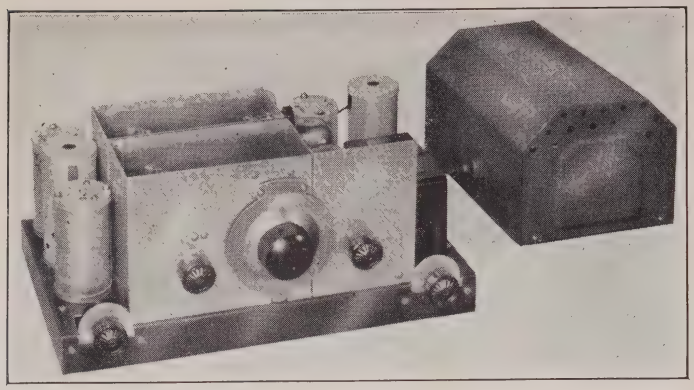
INTRODUCTORY articles of this series considered the characteristics of ultra-short waves, experimental work involved in their exploitation and the general requirements for reception. With the increasing congestion on the quasi-optical channels accompanying more widespread experimentation and commercial use, the desirability for a more selective receiving system becomes a matter of importance second only to the necessity for increasing the range achieved by the superheterodyne and the employment, in it, of developments which reduce background hiss.

*The National Co.

SCHEMATIC WIRING DIAGRAM OF THE ULTRA-SHORT-WAVE SUPER

Figure 1. This circuit diagram shows the exact connections of all the components used in the new set and the dotted lines indicate points where shielding of a high order is essential





FRONT VIEW

Figure 6. Above shows what the receiver looks like with the top of the cans removed and set up alongside of the power pack. At right: Table giving coil data

METERS	NUMBER OF TURNS		TAP-TURNS FROM BOTTOM	
	ANT.	OSC.	ANT.	OSC.
3¾ - 4½	1	¾	¼	¼
4½ - 5½	2	1½	⅜	⅜
5½ - 6½	2⅞"	2⅜	⅜	½
6½ - 7½	3¾	3	½	⅝

receivers and described in detail in Radio News for July.

The first detector and oscillator circuits are tuned by their respective condensers, C2 and C3, of the straight-frequency-line type. These capacitors are double spaced and have maximum capacities of 12 mmfd. The use of isolantite insulation preserves the high-frequency efficiency, and the plates are sufficiently rugged to eliminate microphonic effects which are especially emphasized on ultra-short waves. Condenser C4 is an 8 mmfd. padding condenser which provides excellent tracking, only slight variations of the trimming condenser, C5, being required for the reception of very weak signals.

The tuned circuit L3-C6 is a trap circuit tuned to an intermediate frequency of approximately 1550 kc. Its function is to apply the intermediate frequency to the grid of the detector tube by preventing its return to ground through the low-impedance coil L1. Similarly, L3-C6 offers a low impedance to the signal frequency. It is obviously essential that the losses in this trap circuit be minimized, which consideration predetermines a small-Litz-wound coil and a condenser with a negligible power factor. The capacity to ground must also be low to maintain a minimum circuit capacity. Coil L3 is wound with 100 turns of 10-38 Litz wire on a ⅝-inch form. The tuning condenser may be of the compression type, providing high-grade mica and other fine insulation are used. The capacity required to resonate will be in excess of 30 mmfd., a fairly high capacity being desirable in order to reduce the impedance to the signal frequency.

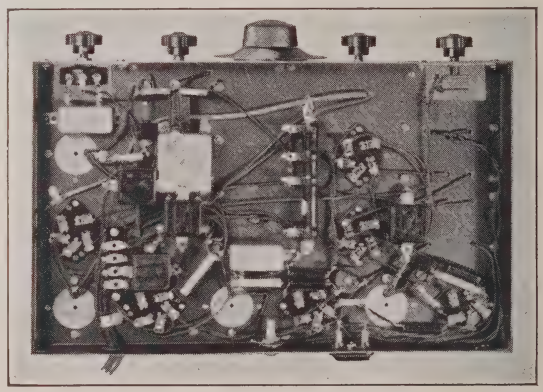
The trap is located in the high-potential side of the grid circuit, so that lower frequency disturbances, such as static, will be by-passed to ground through the tuned-grid circuit.

Electronic Coupling

While the Dow or electronic-coupling system was given detailed description in the July number of Radio News, further explanation is justified in reference to the specific circuit under discussion. The screen grid, the control grid and the cathode of the oscillator tube form the three elements of a conventional triode oscillating system, the frequency of which is governed by the values of L2, C3 and C4. The oscillating variations in the electron stream cause corresponding variations in the plate current which are resistance-coupled to the load or first detector circuit through R8, C21 and R1. It is obvious that the oscillatory impulses are conveyed only through the electronic stream (providing proper shielding is maintained, as is most essential) and that any variation in the load conditions can have no reactive effect on the frequency. It may also be shown that changes in the plate voltage results in frequency-variation effects, through the screen grid and the plate, which nullify each other, the net result being an exceptionally stable oscillating system (comparable to crystal control in stability, but having the necessary advantage of variable-frequency control) which makes the ultra-short-wave superheterodyne practicable.

The First Detector Circuit

The experienced amateur may comment mentally on the fact that grid-leak detection has been employed in this circuit, apparently in defiance of the general favor toward plate-current-curve systems. Simple analysis of the detecting system will indicate that the grid-condenser arrangement is satisfactory for audio-frequency demodulation, but does not offer a sufficiently high impedance to an intermediate frequency to build up an effective grid voltage. However, the trap circuit, which has already been described, overcomes this objection, making it possible to take advantage of the weak signal sensitivity characteristic of grid-condenser detection. It was also found that the resulting use of a positive bias on the first detector (mixing tube) simplified the attainment of satisfactory regeneration, controlled by the variable resistor R4. By increasing the amount of positive bias on the detector grid until the tube drew a few microamperes, detector efficiency was improved, at the same time reducing the required amount of regeneration for a given signal response. The increase in screen voltage required for effective regeneration similarly increased the *apparent* detection efficiency. This may be explained by consideration of the fact that the tube is also functioning as an i.f. amplifier, and the increased amplification accompanying an increase in the screen voltage more than compensates the customary reduction in detector efficiency.



LOOKING UNDERNEATH

Figure 5. This view gives the general idea of the parts disposition under the base

The first detector is followed by a broadly tuned intermediate-frequency amplifier. The three i.f. transformers are tuned only in the secondary circuits, the overall amplification being equivalent to two stages, with both primaries and secondaries resonated to the intermediate frequency. This achieved degree of broadness is desirable, resulting in easier tuning, better quality on amateur signals and television and simplicity of adjustment and increased stability of the receiver as a whole. While, again, the recommendation is for commercially manufactured units, the i.f. transformers can be home-wound on 1¼-inch-diameter dowels with 100 turns of No. 28 wire (primary) and 50 turns of No. 30 double-silk wire on the

secondaries. The secondary is wound first, in a single layer, and the primary, also in a single layer, on top of the secondary, starting at the low-potential end and extending beyond the high-potential end. The lower end of the primary is also the low-potential terminal. Both windings are in the same direction, and may be separated, if desired, by a thin sheet of high-grade insulating paper. The secondary tuning condensers are of the compression type, having ranges between 4 mmfd. and 70 mmfd.

The volume-control action, through variable resistor R10, is limited to the i.f. circuit and has no effect on the plate voltages, in order to eliminate any interaction between the regeneration and the volume controls.

The second detector is of the bias type and outputs directly to push-pull pentodes, type –47. The use of pentodes in this receiver results in a minimum of tubes, with adequate output, a desirable feature in an experimental receiver. The rising a.f. characteristic of the pentode provides a compensatory effect for side-band cut-off in case of excessive regeneration on weak signals.

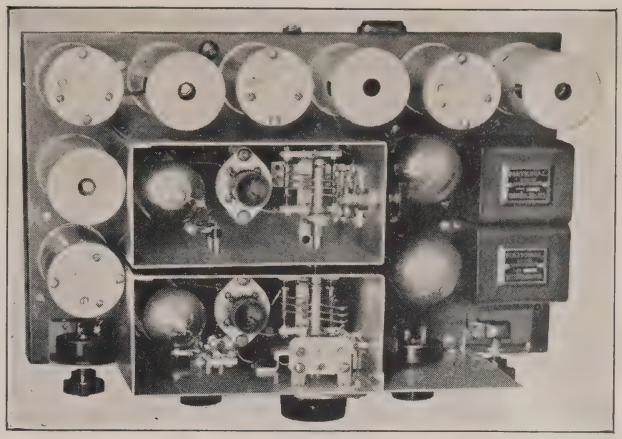
The radio-frequency choke, L4, may be a convenient lattice-wound coil having an inductance of approximately 500 microhenries.

While the beat-frequency oscillator presents nothing novel from a circuit point of view, it must be carefully shielded so that only the correct degree of controlled coupling is effected to the second detector alone. Improper shielding will result in the blocking of the intermediate-frequency amplifier, or result in interference caused by the radiation of spurious harmonics in the high-frequency signal band. The beat-frequency oscillator is also electronic-coupled to the second detector. As the intermediate frequency is constant, the beat note is adjusted, by means of C26, for the desired pitch, after which no further adjustment is required. It is important that this adjustment be made with the station properly tuned. The attainment of this same tone or note may then be used as an indication of perfect tuning on other stations.

Coil L5 can be wound on a 1½-inch diameter R-39 form with 80 turns of No. 28 double-silk-covered wire, tapped 30 turns from the bottom. Condenser C26 has a variable range from 4 mmfd. to 70 mmfd.

The use of a separate beat-frequency oscillator is definitely superior to an attempt to autodyne by introducing regeneration in the intermediate-frequency amplifier. While this oscillator is primarily intended for the beat-note reception of code signals, it is of considerable assistance in the location of television and 'phone stations, and as an indication of frequency modulation or drift.

With the exception of the type –27 second detector and the pentode output tubes, the tubes indicated are all type –24's.



TOP VIEW OF RECEIVER

Figure 4. This illustration shows the location of all parts mounted on the sub-panel. The layout must be followed closely

However, there is no reason why the series types –36-7-8 battery tubes cannot be substituted if it is desired to operate the receiver from a d.c. source.

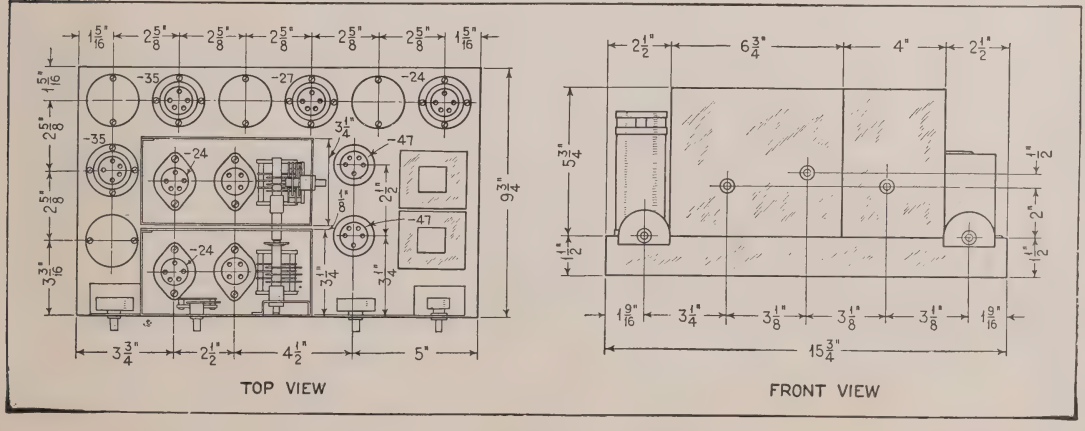
Construction Details

The mechanical requirements of the ultra-short-wave "super" are no less rigorous than the electrical specifications. The general details, suggested in the front-panel layout, Figure 2, the sub-panel layout, Figure 3, and the photographs, Figures 4, 5 and 6, should be adhered to religiously. The chassis and shields must be rigid and conform closely to the indicated dimensions. The recommended layout has been engineered to provide the shortest practical leads between the signal-frequency components of the circuit. The importance of this will be appreciated when it is considered that the total length of wire on a 5-meter coil is approximately 5 inches. The high-frequency wiring should be rigid and, at the same time, highly damped, to reduce the tendency to vibrate. Low-loss parts, such as described in the previous articles of this series and recommended herein, should be employed throughout.

Particular attention has been devoted to the location and connection of by-pass condensers in an effort to reduce regeneration in the intermediate-frequency amplifier. Even a small amount of regeneration will result in a characteristic hiss and a high noise level. Best results will be obtained when the grounded terminals of all by-pass condensers in the i.f. circuit are grounded to a single point on the chassis.

EXACT CONSTRUCTIONAL DETAILS

Figure 3. At left: Gives the exact location of all the parts on the sub-panel, as shown in Figure 4. Figure 2, right: Gives other constructional data, as well as supplying the drilling details for the front panel



The location of this point is not particularly critical, but should be fairly well isolated from the coil shields. Individual grounding at different points results in the existence of r.f. currents in the chassis, often with an appreciable interaction. Also the coils tend to set up similar currents, and if various by-pass condensers are grounded to a point in an area of slight r.f. potential, a certain amount of feedback is bound to be introduced, with resulting instability. I.f. circuit stability is particularly important when it is remembered that the detector regeneration control is also effective in varying the i.f. gain.

A receiver of this type should be mounted in a metal cabinet provided with a metal top, as it is rather difficult to shield the first detector grid circuit (without introducing excessive capacity) from i.f. currents and other strays to which the trap circuit is susceptible.

Another source of instability is feedback through the oscillator-coupling lead connecting to the grid of the first detector. This lead should be connected directly from the plate, through the blocking condenser and coupling resistor to the grid of the tube, and in no way exposed to an intermediate-frequency field. In Figure 4, the detector compartment may be seen adjoining the front panel. The rear compartment contains the oscillator, the padding condenser being mounted above the oscillator tuning condenser, on the end of the can.

Parts List

The parts required for the ultra-short-wave "super" have been suggested in the wiring diagram, and several values have already been indicated in the accompanying text. The recommended parts, which are listed below, may be obtained singly or in a complete construction kit.

1 National chassis, type USW, including shields, cans, sockets, etc.
1 set National ultra-short-wave coils, type USA, USO, UST, USX and USB, respectively (L1, L2, L3, L4 and L5)
3 National intermediate-frequency transformers, type USI (T1, T2 and T3)
1 two-gang National tuning condenser, type SEU, 12 mmfd. (C2 and C3)
1 National antenna series condenser, type USC, 1 mmfd. (C1)
1 National padding condenser, type ST, 8 mfd. (C4)
1 National trimming condenser, type ST, 2 mfd. (C5)
5 compression-type condensers, 4-70 mmfd. (C6, C12, C13, C15 and C26)
3 Aerovox .5 mfd. condensers (C7, C9 and C11)
6 Aerovox .01 mfd. condensers (C8, C10, C14, C16, C20, C24, C25 and C27)
2 Aerovox .001 mfd. condensers (C17 and C18)
4 Aerovox .0001 mfd. condensers (C19, C21, C22, C23)
2 Lynch 100,000-ohm resistors (R1 and R7)
3 Lynch 5-megohm resistors (R2, R3 and R13)
2 National variable 50,000-ohm resistors, type USR (R4 and R10)
3 Electrad type C voltage dividers with necessary clips, 10,000 ohms (R5 and R16)
3 Lynch 20,000-ohm resistors (R6, R8 and R12)
2 Electrad wire-wound 500-ohm resistors (R9 and R11)
1 Electrad wire-wound resistor 220 ohms (R14)
1 Electrad wire-wound, center-tapped resistor, 60 ohms (R15)
1 National input transformer, type P-50 (T4)
1 National output transformer, type P-11 (T5)

Adjustment and Operation

The indicated voltages should be applied to the tuner from an adequate power supply and the taps adjusted on resistors R5 and R16 until the tube voltages at points 1, 2 and 3 are respectively 67.5 volts, 135 volts and 135 volts.

The controls shown on the front-panel layout and photograph are, from left to right: first detector regeneration, first detector trimmer, tuning control, i.f. gain and heterodyne-oscillator switch. The adjustment and operation, in general, are similar to corresponding operations on a conventional superheterodyne. The intermediate-frequency amplifier should first be lined up with the aid of a local oscillator, coupling directly to the grid of the first detector tube. The high side of the coupling should then be transferred to the high-potential side of C2 and the connection opened between the high side of C2 and L1. Condenser C6 should then be adjusted for minimum signal. This will tune the trap circuit to the intermediate frequency.

In operation, the trimmer should be adjusted for the greatest background hiss. The regeneration control is operated in the usual manner — up to the oscillation point. When the detector spills over, the receiver ceases to function, due to overload change in bias, etc. The operator will readily become accustomed to this minor peculiarity.

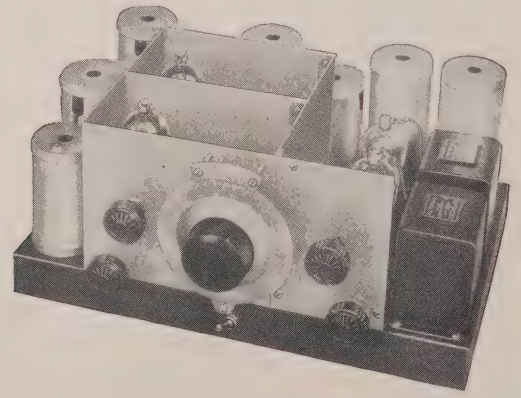
The receiver described above is the result of experimentation over a period of years, brought up to date with reception tests from the most modern ultra-short-wave transmitters. The predominant contrasts between this superheterodyne and the best of the super-regenerators are increased selectivity and sensitivity. While ease of control is in favor of the super-regenerator, these two advantages in the present receiver more than justify its use.

A signal which is just above the threshold value on the super-regenerative receiver is easily tuned in on the superheterodyne without adjustment of the oscillator trimming condenser. With the aid of this last-named control the signal can be easily brought up to loudspeaker volume, demonstrating the superiority of the superheterodyne.

In addition to co-operation from several amateur stations, tests have been made on signals transmitted from the Empire State Building, New York City, at a distance of 15 miles, with results indicating an excellent degree of selectivity, with a sensitivity unapproached by any other type of ultra-high-frequency receiver.

At present R. S. Kruse is using one of these new Ultra Short Wave superheterodynes in his laboratory at Hartford, Conn., in an attempt to receive some "high angle radiation" 5-meter signals being sent from the West Coast by a special very high powered experimental transmitter erected by the engineers of Station W6XAD in Los Angeles.

While it is still much too early to tell anything of the actual results obtained, or not obtained, in connection with these tests, they have afforded an opportunity for numerous checks on the reception from the NBC ultra short wave transmitter atop the Empire State Building in New York City. The receiving station in Hartford is approximately 90 air miles from the New York transmitter and consequently well beyond the so-called "optical transmission limits"; nevertheless, Kruse reports good reception from this transmitter particularly at just about the time of sunset.



AMERICAN RADIO RELAY LEAGUE ACTIVITIES

on the

56-MEGACYCLE AMATEUR BAND

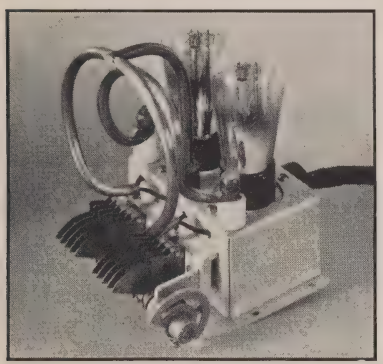
Much of the present activity amongst amateurs on the 5-meter or 56-megacycle amateur band is due to the activities of the staff of *QST* magazine, headed by Ross Hull and James J. Lamb, in developing a series of highly practical and yet very inexpensive ultra-high frequency transmitters and receivers.

It has been the policy of Messrs. Hull and Lamb and their associates, to concentrate on the development of inexpensive and readily constructed apparatus, consequently their transmitters have, almost without exception, been of the self-excited push-pull oscillator variety, and their receivers of the super-regenerative type.

On this page we show their preferred transmitter and receiver circuit diagrams with necessary constants; also two views of an exceedingly compact super-regenerative receiver employing this circuit diagram. Three distinct types of transmitters are shown, although they all employ somewhat similar circuits. Perhaps the simplest and yet most practical transmitter is that shown in the upper left-hand corner, which follows the circuit diagram almost exactly in its layout. The illustration in the lower left-hand corner is of a very compact portable 'phone transmitter, employing a "T.N.T." circuit. Two additional tubes are added to serve as modulators.

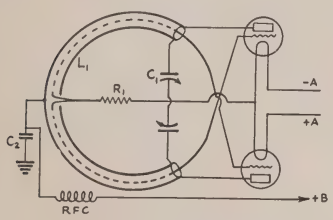
The illustration below is of an oscillator placed directly in the physical center of the doublet antenna system, the modulator being located along with the power equipment at some distance away and modulated plate voltage being supplied to the combination oscillator-antenna system by the cable shown.

Full details on the construction and operation of the receiver and transmitters shown on this page appeared in the June and December (1932) issues of *QST* magazine.



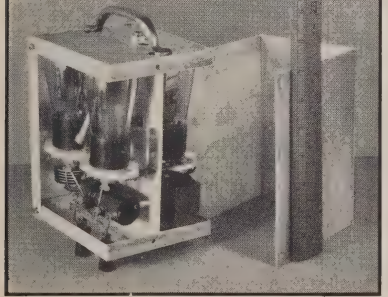
THE UNITY-COUPLED PUSH-PULL OSCILLATOR

Arranged so that its tank is a single turn well out in fresh air, this oscillator gives a performance superior to that of the older rigs. The ends of the tank coil are soldered to the condenser stator lugs.



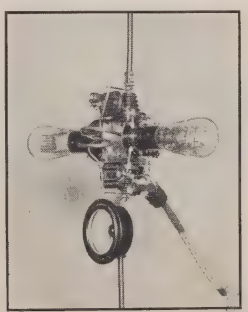
THE OSCILLATOR CIRCUIT

L_1 — *One turn of ¼" copper tubing 3⅜" inside diameter.*
C_1 — *Double Midget variable condenser (33 μμfd. per section). (Such as National STD35).*
C_2 — *.0001-μfd. fixed condenser.*
R_1 — *100,000-ohm 1-watt fixed resistor.*
RFC — About 20 well-spaced turns of No. 26 wire on ¼" dowel. The antenna coil, visible in photograph, is 2¼" inside diameter.



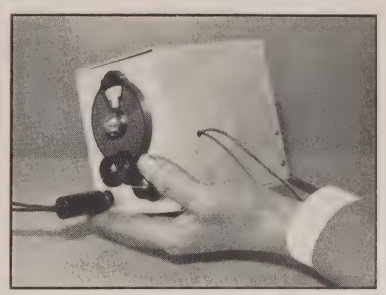
COMPACT OSCILLATOR AND MODULATOR

The three-sided cover, released with a few turns of the screwdriver, allows quick tube replacement or examination of the set.



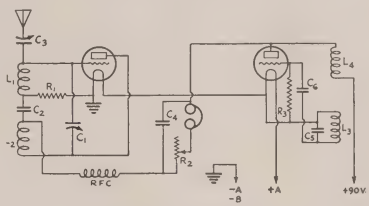
STILL ANOTHER STYLE OF 56-MEGACYCLE OSCILLATOR

With a pair of Type '10 tubes supplied with 400 volts the antenna current is usually more than 1 ampere with the transmitter indoors — about ½ ampere when located in the open.



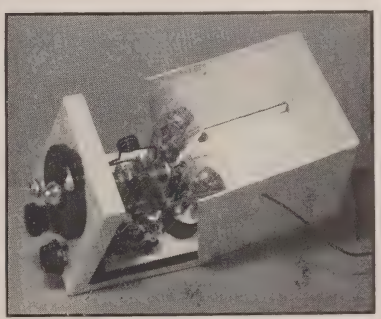
AND NOW BRING OUT YOUR SMALL RECEIVERS!

The two-tube super-regenerative 56-mc. receiver.

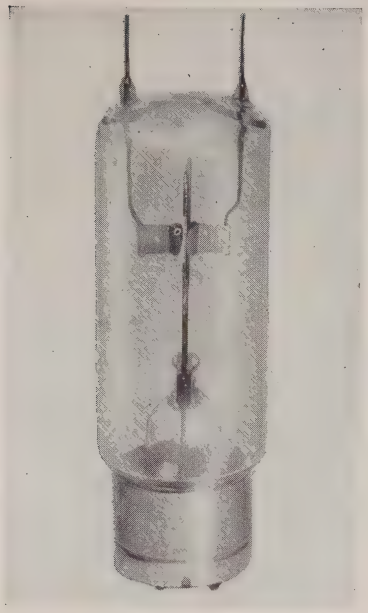


THE WIRING OF THE MIDGET SUPER-REGENERATIVE RECEIVER

C_1 — *20-μμfd. three-plate midget variable.*
C_2 — *150-μμfd. fixed condenser.*
C_3 — *Trimmer condenser (mica dielectric) set near zero.*
C_4 — *.001-μfd. fixed condenser.*
C_5 — *.002-μfd. fixed condenser.*
C_6 — *.0005-μfd. fixed condenser.*
R_1 — *1-megohm fixed resistor.*
R_2 — *50,000-ohm variable resistor.*
R_3 — *50,000-ohm fixed resistor.*
RFC — 30 turns of No. 26 wire on ¼" rod.
L_1, L_2 — *Each three turns of No. 16 enamelled antenna wire ½" inside diameter.*
L_3, L_4 — *1400 and 900 turns, respectively, of No. 34 silk-covered wire wound on a ⅜" dowel between cardboard disks spaced ¼".*
The tubes are Type '30 with a 4-volt "C" battery serving as filament supply.



WITH THE COVER OPEN: A VIEW INSIDE THE TWO-TUBE SET



THE MAGNETRON
Figure 1. The tube which with its field coil offers new fields of experimentation on the ultra-short waves

HOW TO CONSTRUCT MAGNETRON

Here it is, something new in radio! A new employing the gridless double plate tube in a Gill-Morill method. This article, a feature of short wave field, will be invaluable to the

By James

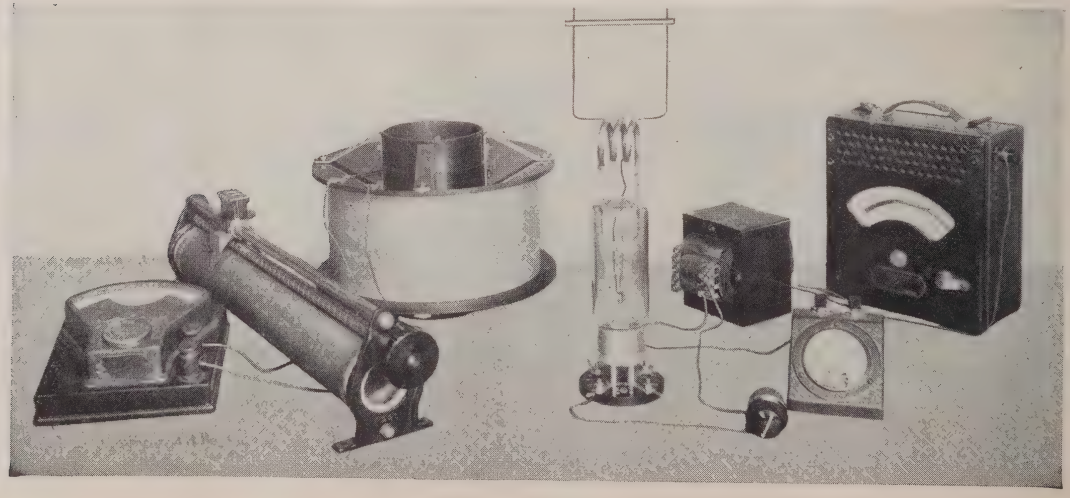
THE American amateur was the first to make practical use of the 200-meter band, and the first to develop the utility of still shorter and vastly more important communication channels. A new field of research, the ultra-short waves, now challenges his ingenuity, and we are sincere in our belief that here again the "ham" will make a genuine contribution to ultra-high-frequency technique. The magnetron, in particular, offers fertile possibilities, and its application to commercial enterprise may be, to our way of thinking, materially accelerated by its exploitation and development in the amateur ranks. This article finds dual justification in the effort to stimulate such experimentation, and in presenting a practical 56-megacycle magnetron transmitter.

As we pointed out in the original article of this series, there exist a variety of methods whereby ultra-short-wave energy can be set in motion. However, the necessity for efficiency (reasonably high-power output for practical input powers) and stability places a definite limitation on the systems serviceable for useful communication. The magnetron, today, offers the most economical method for generating quasi-optical power. As it is an electronic device, its functioning is perhaps best understood by indicating its similarity to more conventional systems. It is not particularly difficult to design the usual sort of tube oscillators for wavelengths between 5 and 10 meters, and by the utilization of their harmonics to extend this range to a still lower minimum. However, as might be imagined, the stability of such systems leaves much to be desired, and the power output is generally inadequate. Also, as may be readily understood, maximum frequency limitations are necessarily imposed by considerations of the capacity and inductance by which resonance is determined. An additional complication, the fact that as the frequency is still further raised the period approaches the times required for the electrons to complete their inter-electrode cycle, imposes further limitations—at the same time offering a solution to the problem. It was found that, under proper conditions, oscillations could be sustained the frequency of which was dependent on the geometry of the tube or on the potentials applied to the elements, rather than upon the LC characteristics of the circuit. Such systems have been described categorically as Barkhausen-Kurz circuits in deference to their two most-prominent investigators. It is logical and true that such arrangements are capable of delivering higher powers, at very short wavelengths, than those with which we have become familiar on the conventional short waves. It was also discovered that the power output could be increased by resonating the circuit to the natural electronic frequency, and such transmitters have

* The National Co.

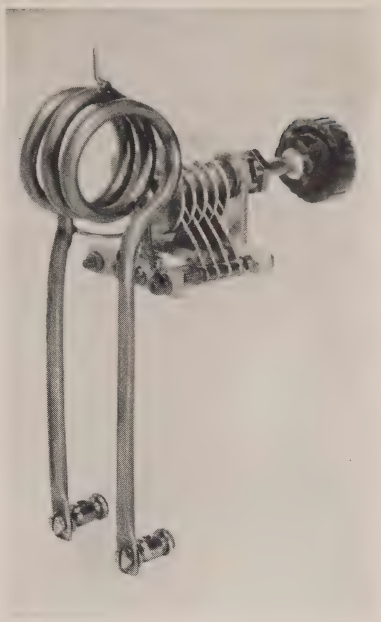
SET-UP OF THE NEW TRANSMITTER FOR 1½ METERS

Figure 2. This illustration shows the essentials of the magnetron oscillator system. The field coil, rear center, has been removed from around the tube for clarity. The particular arrangement shown is for a frequency range corresponding to approximately 1½ meters. The plate supply circuit is not shown



A 56 MEGACYCLE TRANSMITTER

oscillator principle for the ultra-short waves manner comparable in many respects to the the* RADIO NEWS *series on opening up the ultra-technician and earnest experimental amateur



THE HIGH C TUNER

Figure 10. This is the tuned circuit for resonating the new magnetron oscillator tube as explained in the text

Millen*

come to be known as Gill-Morill circuits and are comparable in many respects with the magnetron system.

The magnetron is not a new tube. It has been with us for well over a decade, and was originally designed as a tube in which electron control was effected by magnetic influence rather than electrostaically. In other words, the grid of the tube was a magnetic coil, and, peculiarly enough, the magnetron was first used as a radio-frequency amplifier and oscillator in the neighborhood of 8000 meters!

The magnetron used in ultra-short-wave work varies from its prototype in several essentials. The magnetic coil no longer functions as a grid (in the control sense), but its effect is similar to that of a "bias." By increasing the magnetization current, the space current can be cut off—corresponding to an increase in negative bias in a conventional triode circuit. At optimum magnetic bias, the space current is reduced while space charges build up within the tube. Connected with a suitable circuit, a negative-resistance characteristic permits these charges to dissipate and reaccumulate, producing a cycle the time constant of which is partly determined by the spacing of the elements, the intensity of the magnetic field and the potentials applied. Subsequent experiments have shown that, as in the Gill-Morill circuits, the efficiency of the magnetron is greatly increased when the circuit resonance approaches the natural electronic period.

The magnetron used in the experiments and transmitter to be described is the GE-239, and is shown in Figure 1. The anode is split into two semi-cylindrical sections mounted coaxially with the heavy tungsten filament. It is an air-cooled tube, used principally as an oscillator. The lowest operable wavelength is .75 meters, and at 1 meter, with a plate potential of 1500 volts, has a plate impedance of 5000 ohms. The maximum operating anode potentials are 1500 volts d.c. and 2000 volts r.m.s. a.c. The maximum d.c. anode current is .075 ampere, and the maximum plate dissipation 60 watts. The inter-electrode capacities are anode-to-anode (filament grounded) .5 mmfd.; anode-to-filament (other anode grounded) .7 mmfd. The tungsten filament draws 5 amperes at 5 volts.

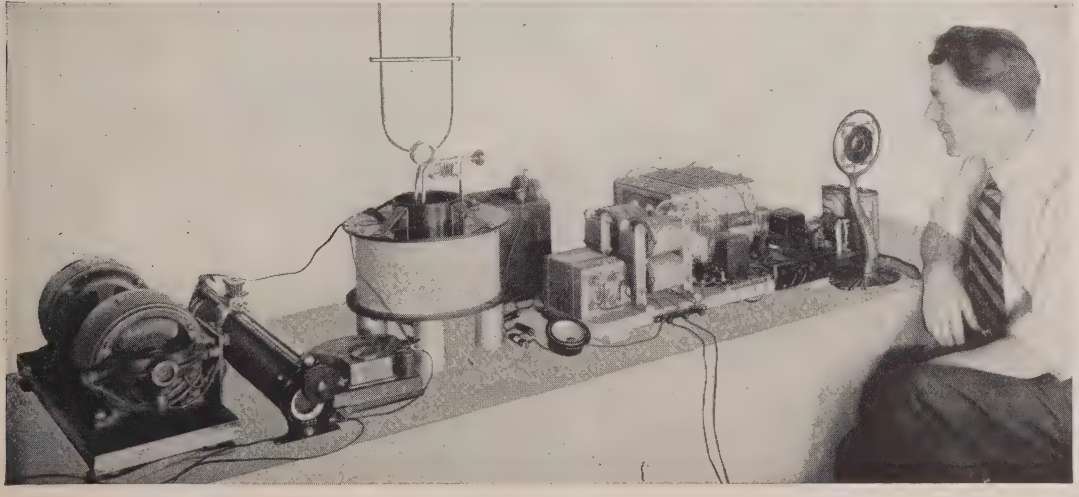
The mechanical characteristics of the tube are indicated in the photographs. The anodes are connected from the top, and the base plugs into a standard 50-watt socket. The overall length is 10 inches; diameter 2¼ inches.

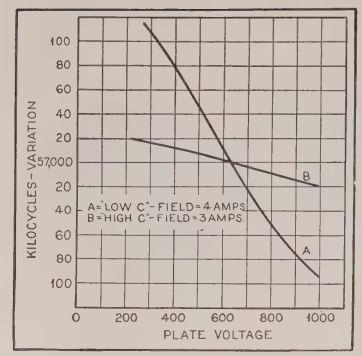
The output of this tube, in both power and stability (when properly operated) is definitely superior to other arrangements, its output at .75 meter being vastly better than that available with the B-K G-M circuits.

Figure 2 shows the experimental layout from which the various data accompanying this article were secured. The circuit, as may be observed from Figure 3, is simplicity itself.

COMPLETE 5 METER AMATEUR PHONE TRANSMITTER

Figure 8. Robert McCoy of the Jackson Research Laboratories shown operating the station. The high C tuned circuit may be seen just above the field coil which is in correct position surrounding the coil. Speech amplifier equipment is at the right energized by a storage battery and B batteries. The motor generator supplies the field coil energy



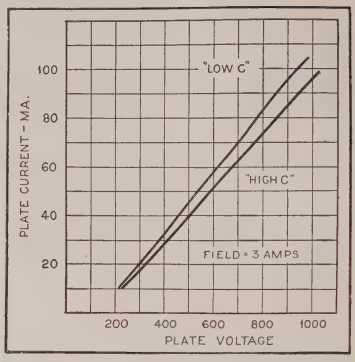


FREQUENCY VARIATION

Figure 4. Curves showing increased stability by using high C circuit

LOW C COIL

Figure 9. This is the tapped four turn low C coil used in the original experiments



MODULATION DATA

Figure 7. Linear relation of plate voltage-plate current adapts the magnetron readily to modulation

It consists of the tube between the anodes of which is connected the center-tapped coil. (As will be described, this coil was changed in the course of the experiments, and an exterior capacity shunted across it. The simple inductor is shown in Figure 9 and the coil plus the tuning condenser, are shown in Figure 10.) The field coil has been removed from its place around the magnetron for the sake of clarity.

The oscillating frequency is largely determined by the inductance and the capacity of the circuit. For the highest frequency (400 megacycles), the inductance of the anode leads and the capacity between them is sufficient. In this case the external anode leads are short-circuited with a copper bar or ribbon) about one inch from the glass, and the high voltage is connected to a tap at the center of the bar.

The Field Coil

The field coil is wound with 70 pounds of number 14 enameled wire, on a form having an inside diameter of 5 inches. The length of winding is 5 inches, 74 turns to the layer, with a total number of 2665 turns. Each layer is separated with paper insulation .015-inch thick. The coil is excited with a potential of 100 volts through a suitable reristor, providing a maximum current of 5.8 amperes and a maximum continuous field strength of 830 gauss with a dissipation of 580 watts. The outside diameter of the coil is 11 inches. The variable series resistor should be capable of carrying the maximum excitation current and should have a resistance of at least 17 ohms.

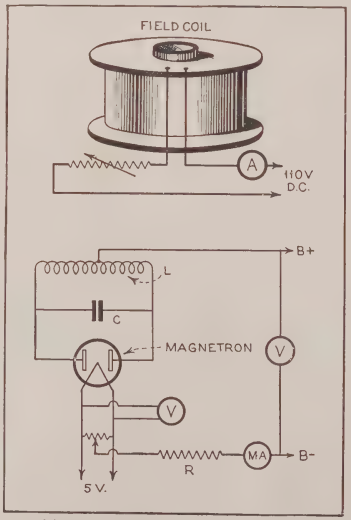
The effect of the magnetic field on the operating characteristics of the magnetron is, as we have already suggested, somewhat similar to that of a bias of the grid of a triode oscillator. At low values of field, below 2½ amperes, corresponding to a small bias, the plates heat excessively; the plate current is high and the efficiency is low. As the field is strengthened, the circuit becomes more stable, operating with greatly improved efficiency and output. The current in this region varies from 3 to 5 amperes. Plate-current "cut-off" can be obtained with an excitation current of about 7 amperes.

In general, the requirements of the oscillatory circuit, in respect to efficiency, stability, etc., are similar to those of the dynatron oscillator, although, of course, the frequency range is much greater.

As the filament is tungsten, it is possible to operate it over a wide range of voltages without encountering the trouble experienced with thoriated filaments. It was found, however, that for best stability the filament should be operated near its rated voltage—though a 10 or 15 per cent. variation has a relatively small effect.

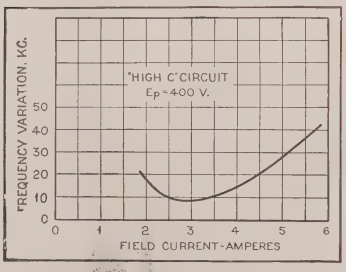
The first tests, while altogether satisfactory in respect to output, left a great deal to be desired from the standpoint of stability. Curve A, of Figure 4, illustrates the manner in which frequency varied as the plate voltage was changed. In this original experiment the tuned circuit consisted of 4 turns of ¼-inch copper tubing, 2 inches in diameter, mounted directly on the anode leads, the tuning capacity being the inter-electrode capacity of the tube (about .5 mmfd.) and the distributed capacity of the coil and leads. The frequency was approximately 56 mc. The circuit and operating conditions under which this test was made probably represented the most unfavorable, with respect to frequency stability, that would be encountered in practice.

The total change in frequency, i.e., about 200 kc., seems rather appalling to one familiar with the operation of low-frequency apparatus. As a matter of fact it is not much worse than that encountered in a self-excited push-



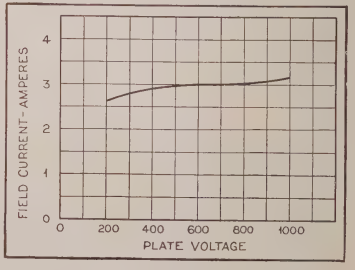
THE MAGNETRON CIRCUIT

Figure 3. The data supplied in this article was obtained from a transmitter using this simple circuit. The top diagram shows field coil hook-up



CHOOSING PROPER CURRENT

Figure 5. Showing relation of field-current ripple and frequency variation with the high C circuit



OBTAINING MINIMUM VARIATION

Figure 6. This is a field current, plate-voltage curve for getting the least frequency variation

pull oscillator operating on the same ultra-high frequency. Such an oscillator, however, cannot be considered satisfactory. An investigation (with the idea of improving stability) was therefore begun, and while it is not fully completed, it represents definite steps in the right direction.

Stabilizing the Circuits

Each portion of the magnetron circuit has a relationship to frequency stability. Variations in the magnetic field were very bothersome, so it was deemed advisable first to investigate this. It was discovered that when a certain magnetic field strength was employed, variations in the field current had a minimum effect on frequency change. The optimum field current, from this point of view, was about 4 amperes. This is important since the field-supply filtering is something of a problem, due to the high current required. In these tests a motor-generator furnished the field power and when the correct adjustment was attained, a monitoring test disclosed the fact that such disturbances as commutator ripple and minor line-voltage variations were no longer of major importance. The magnetron was not operating quite at its maximum efficiency at this field setting, but the drop in efficiency was small enough to be considered important in the light of the improved stability obtained.

The frequency variation, with change in plate voltage, was still the same, however, so the "low C" circuit was abandoned in the hope that a certain amount of tuning capacity would be beneficial. The magnetron operates most efficiently into an oscillatory circuit of high impedance, making a "high C" circuit theoretically undesirable. Nevertheless a tuned circuit was constructed employing a coil of 3 turns of ¼-inch copper tubing 1½ inches in diameter, tuned with a condenser of about 20 mmfd. capacity. Since the inter-electrode capacity of the tube is only about .5 mmfd., this additional capacity effected a considerable improvement in stability, without serious loss in efficiency.

The operation of the circuit, as a whole, was quite different from the original tests. Changes in field current, plate and filament voltages caused only a relatively small variation in frequency. The curves in Figure 4 show the contrast between the "low" and "high C" circuits.

A definite value of field current which minimized the effects of commutator ripple, etc., was found as before, but was considerably lower in value, being approximately 3 amperes instead of 4 amperes (Figure 5). It is interesting to note that the optimum operating value of field current, with regard to frequency instability caused by field variation, is approximately the same at all plate voltages, as is shown in Figure 6. As before, better output was obtained with the field current reduced slightly from that value giving most stable operation. The choice of field current will therefore depend somewhat on operating conditions. If a well-filtered supply is available, efficiency and output are the deciding factors. Where the field supply is subject to variation, stability is the predominant consideration.

The value of R is not critical as far as efficiency or frequency vs. plate-voltage variations are concerned. However, it was found that by the correct adjustment of R, frequency variations due to field strength changes could be still further reduced materially. The actual value varies between 100 and 400 ohms and depends on the plate voltage — higher resistance being required for higher potentials. Some energy is necessarily dissipated in this resistor, but this loss is relatively unimportant in view of the main goal of a stable circuit. Also, some compensation of this loss is achieved through an improved anode circuit efficiency.

A d.c. Filament Source Preferred

After a fair degree of stability had been attained, as indicated in curve B, Figure 4, another source of trouble became evident. This was vibration of the filament structure of the tube, due to the filament current, which was alternating current, reacting in a "motor" effect with the strong d.c. field. When the filament was light by d.c., this trouble was eliminated.

Modulating the Circuit

Referring to the curves in Figure 7, it is immediately seen that the relation between the plate current and plate voltage is essentially linear, and the circuit, therefore, lends itself admirably to modulation. From the slope of the curve, the effective plate impedance is found to be about 9000 ohms, which, while somewhat higher than that commonly encountered in the usual transmitting tubes of similar power, should present no serious difficulty from the standpoint of obtaining a satisfactory impedance relationship in the modulator output circuit.

Photograph, Figure 8, shows the complete set-up of the magnetron, with its attendant apparatus, including modulation and speech equipment. The modulator consists of two type –50 tubes in push-pull, connected through a suitable transformer to the oscillator plate circuit. Since the magnetron was operating with an input of about 35 watts at 650 volts, a fair percentage of modulation was obtained with the two –50's operating at the same plate potential. In any case the modulation should not exceed 70% if reasonably good fidelity is desired. The speech equipment and amplifier circuits are quite conventional.

The radiating system was a simple vertical, half-wave, copper-rod antenna approximately 8 feet long, and fed by means of a balanced transmission line.

Transmitting Tests

Field tests were made up to distances of about 5 miles, the signal being checked in comparison with that of a conventional modulated oscillator. Two types of receivers were used, one being a super-regenerator, and the other the latest type of ultra-high-frequency superheterodyne described in Radio News for August. It was, of course, impossible to check the effects of frequency modulation of the super-regenerator since the receiver itself is subject to a degree of frequency modulation from the suppressor frequency that is comparable with that of the worst transmitter. Due to this fact, only slight differences between the transmitters were apparent on the first receiver (the signal from the magnetron was appreciably sharper, but the tone quality was not noticeably better).

On the other hand, when using the superheterodyne, the magnetron was found to give a clear-cut signal of good quality, in contrast to a decidedly broad and wobbly signal of low intelligibility from the modulated oscillator.

The tests definitely checked the various circuit requirements that laboratory experiments had indicated to be desirable. Of the two transmitters, each employing similar modulating equipment, the magnetron gave a much stronger signal due, of course, to the higher degree of efficiency. Increased power at these frequencies does not result in a corresponding extension of range, since the behavior of the signal tends to comply with optical laws. However, the stronger signal was found to be much more effective in locations subject to local interference.

The possibility of modulating the r.f. output of the circuit by supplying the modulating power to the field coil will doubtless occur to many experimenters. However, aside from the difficulty of controlling the high excitation current with any depth of audio-frequency variation, field circuit modulation might be undesirable due to the excessive change in radio-frequency with field current change. Also, the r.f. output does not vary uniformly with the field, except over rather small limits and when using a somewhat restricted range of plate voltages.

Higher Frequency Possibilities

The tests described above were confined to the neighborhood of 56 megacycles. A vast amount of experimentation still remains before the possibilities of the magnetron are fully realized on frequencies above 300 megacycles (below 1 meter). Work in this region, which is not being used at present for any practical purpose, affords a highly interesting and unusually fertile field for the experimenter, and the magnetron, at the present time, is the tube which seems best suited for this phase of exploration.

NOTE

Since the experiments outlined above were performed, a paper by G. R. Kilgore appeared in the November (1932) issue of The Institute of Radio Engineers PROCEEDINGS, entitled "Magneto Static Oscillators for Generation of Ultra Short Waves." This paper describes in detail the operating characteristics of magnetron oscillators operating in the neighborhood of 42 cm.

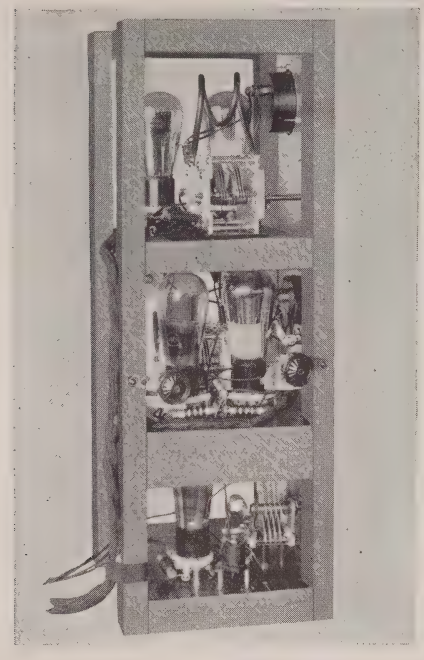
Mr. Kilgore found that in order to obtain good efficiency, the field must be inclined at a slight angle to the axis of the tube, the angle in most instances being between four and six degrees. The action of the tube at a wavelength of 42 cm. is somewhat different than that at five meters, and when operating at this latter wavelength it was not found necessary to incline the field coil any given amount.

The effect of such an inclination, if any was present, was so extremely small as to escape the observation of the author and it is certainly not necessary for stable operation with good efficiency at these longer wavelengths.

From the results of these experiments and those described by Mr. Kilgore, it is probable that the dividing line where the field angle becomes important is between 150 and 250 cm.

Should the experimenter desire to use a magnetron oscillator on the ¾ meter amateur band, it is recommended that he first look into the Kilgore paper.

THE FUNDAMENTAL CIRCUIT DETAILS AND CRYSTAL 56 MEGACYCLE



RIGHT SIDE VIEW

Figure 6. This illustration shows the recommended construction for the new transmitter

Engineering considerations involved in end of the radio wavelength spectrum The amateur and experimenter are tions to the radio science have been directed to the intriguing possibilities through the use of crystal

[*By* James

MUCH of the necessary engineering procedure in the design of ultra-short-wave transmitters and receivers is implied in the fundamental equation which states that the frequency of a tuned circuit is equal to the reciprocal of 2 pi times the square root of LC. Inspection of this equation will show that, as the frequency is raised, the quantity under the radical sign must become smaller and smaller. In the higher region of megacycles the LC constant is in the magnitude of a single unit times 10^{-18}! It immediately becomes evident that even an infinitesimal variation in capacity or inductance may represent an appreciable fraction of the whole and may result in a considerable frequency shift. In a typical broadcast receiver, tuned to the center of the broadcast band, the variation of 1 micromicrofarad in tuning capacity will effect a frequency change in the order of 1.5 kc. A similar capacity variation at 56 megacycles will cause a frequency shift *one thousand times as great!*

Connection leads which were considered short in conventional high-frequency receivers are impossibly long in ultra-high-frequency design. Circuit capacities which were believed at an absolute minimum, two years ago, would place definite tuning limitations in the ultra-short-wave transmitter or receiver. A slight turn in a lead will so boost the inductance as to render the apparatus inoperable at the desired frequency.

Obviously the least vibration in the wiring or parts of the equipment will cause momentary frequency shifts, or modulation, to an intolerable degree.

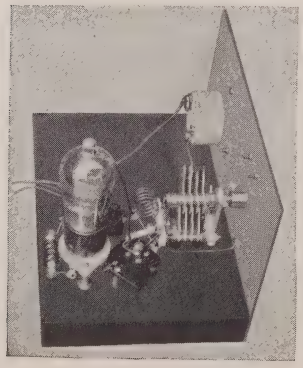
Similar consideration of other factors influencing frequency, such as slight plate-voltage variations and electronic peculiarities, which are hardly of vital import on longer waves, disclose another fundamental source of frequency instability and modulation, which, unless definitely circumvented, severely limits the possibilities of the quasi-optical waves for communication purposes. Indeed, the outstanding characteristic of the popular ultra-high-frequency transmitters operating in the amateur 5-meter band is the extreme degree of frequency modulation. The use of a self-excited oscillator with Heising modulation (the conventional arrangement) results in a frequency shift, over the complete audio cycle, which is often as high as 200 kc.

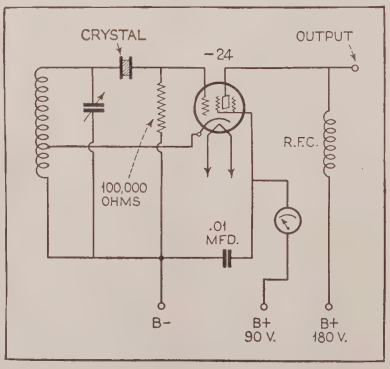
The "wobbulation" of such a transmitter is not noticeable when reception is effected on a super-regenerator, due to the fact that the receiver itself is continuously sweeping over a wide frequency range in variations caused by the action of the interruption frequency on the detector circuit. In other words, the frequency stability of the receiver is of the same order as that of the transmitter, with the net result that the deficiencies of the latter are not noticeable. As a matter of fact, even a sharp transmitter, confining its signal to a band 10 kc. wide, would seem equally broad on the super-regenerator! However, on better receivers, such as the ultra-short-wave superheterodyne described in RADIO NEWS for August, the modulated-oscillator type of transmitter is immediately shown up in its true colors and is, in many instances, incapable of transmitting intelligible speech to such a receiver.

By some, this may be construed as an argument in favor of the super-regenerator—but such an argument, at the same time, is an admission of experimental defeat. The super-

THE CRYSTAL CONTROL APPARATUS

Figure 1, at right, contains the fundamental crystal circuit. The constants are arranged so that it will just oscillate off the crystal frequency. Figure 4, at left, gives the layout of the tourmaline crystal unit, which comprises the lower panel in the transmitter, shown in Figures 6 and 7





* The National Co., Inc.

CONSTRUCTIONAL DATA FOR A PRACTICAL

CONTROL TRANSMITTER

the development of the high-frequency require unusual ingenuity and technique. instinctive pioneers and their contribu- considerable. Their attention is now of the ultra-high-frequency channels control transmitter circuits

Millen*]

regenerator is, in effect, a "pound of" cure. As was pointed out in the article referred to above, full advantage of the ultra-short-wave field can be taken only with sharply tuned and highly sensitive receivers. The problem therefore resolves itself into the design of stable ultra-high-frequency transmitters.

The possibilities of the magnetron offer one solution of the problem, and a thoroughly practical transmitter of this type was described in the preceding article of this series. To the experimenter, undeterred by the field power requirements and its unconventionality, the magnetron, as was demonstrated, provides a fertile field for research. However, to amateurs intimately acquainted with crystal-controlled transmitters on lower frequencies, the possibilities of this more familiar method of frequency stabilization will immediately present themselves—as well as the associated problems.

As radio developments go, quartz crystals have been long used for frequency stabilization in virtue of their piezo-electric or mechanical-electric effect. Placed in a suitable circuit, they limit the oscillations of that circuit to a definite single frequency. Quartz crystals are cut parallel to the optical axis and are capable of vibration along any one of three electrical axes. (An exis is a convenient way of referring to the most efficient path, through a crystal, traversed by a vibratory phenomenon. The optical axis, for instance, refers to the line through which light will be passed without causing double images, or other aberrative phenomena, depending upon the characteristic of the crystal.) The dimensions of the crystal determine the frequencies at which it will oscillate, and for the highest frequencies the thickness of the plate (the smallest dimension) is the deciding factor. The resonating wavelength of a quartz crystal is generally about 110 meters for each millimeter thickness. This consideration logically imposes a limitation upon the lowest wavelength which it is practical to attain. A 5-meter crystal, for instance, would be only 1/22nd millimeter thick—about 1.8 thousandths of an inch! A quartz crystal of this thickness would be quite incapable of standing the gaff. Much thicker crystals disintegrate explosively under the electrical and mechanical stresses of operation. Also, even when operated inefficiently at low powers, ultra-high-frequency quartz crystals give rise to spurious frequencies neighboring the predominant resonance point, resulting in a form of instability quite similar to and as iniquitous as that they are designed to eliminate.

VIEW FROM THE LEFT

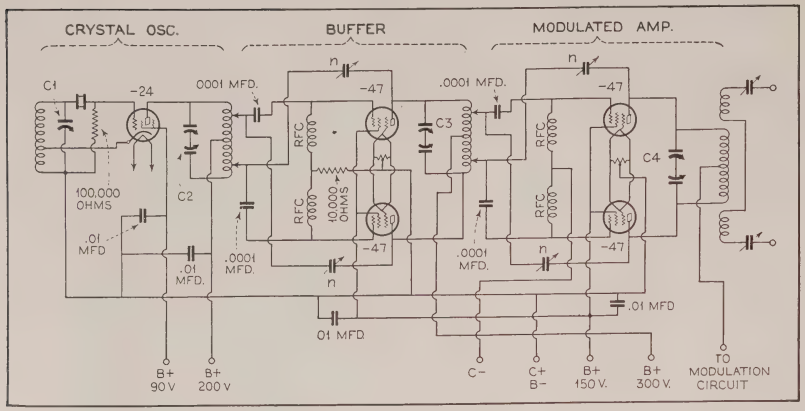
Figure 7. This shows the details of construction of the buffer stage and r.f. amplifier

An obvious but theoretical solution to ultra-short-wave, quartz-crystal stabilization is by means of repeated frequency doubling. This is cumbersome and expensive, however, due to the fact that the harmonics are excessively weak, requiring amplification following each doubling stage—resulting in an impractically elaborate set-up.

A real solution to the problem exists in the use of tourmaline (in place of quartz), which permits the operation of the ultra-short-wave transmitter at the fundamental crystal frequency. While the tourmaline piezo-electric constant is about 10% less than quartz, it is altogether adequate for oscillating purposes without use of excessive powers, and even when ground to quasi-optical frequencies, exhibits none of the instability characteristics of quartz. A great deal of the preliminary experimental work on tourmaline crystals has already been done in the American Radio Relay League laboratory at Hartford under the direction of James J. Lamb and reported in the amateur periodical, *QST*. It is also considerably more rugged, suffering no serious consequences even under ultra-high-frequency

THE COMPLETE SET-UP IN OPERATION

Figure 8. The transmitter being operated by Lloyd Green, radio editor of the Boston Globe. It is used in conjunction with a class B modulator shown in the center. The receiver is the ultra-short-wave super described in the August issue



SCHEMATIC DIAGRAM OF THE COMPLETE SYSTEM

Figure 2. This is the scheme of connections for the 56-megacycle crystal-control transmitter. The crystal is ground to the transmitter frequency—no doubling being required

overload, and, as its electrical-mechanical ratio is approximately 80 meters for each millimeter thickness, the plates are approximately 35% thicker than quartz for a given frequency. Circular tourmaline plates also have a smaller diameter than corresponding quartz plates, resulting in an additional strength. A 5-meter tourmaline plate is about 2.5 thousands of an inch thick and about ⅜ inch in diameter. As a matter of incidental interest, the optical axis of tourmaline coincides with an electrical axis, and the plates are therefore cut perpendicular to the optical axis.

The Crystal Oscillator

The fundamental crystal circuit is shown in Figure 1, and while it varies only slightly from several conventional arrangements, the departures represent the result of considerable engineering and experimentation. The constants of this circuit are such that sufficient regeneration exists to sustain oscillations when the crystal is replaced by a grid condenser. When the crystal is substituted for the grid condenser, the circuit will still function as a self-excited oscillator until the crystal frequency is approached, at which time the crystal will snap into control and maintain it over a considerable range of tank-condenser settings. The milliammeter connected in the screen circuit will show an increase in current as the crystal resonance point is approached, followed by the familiar decrease in current as crystal-controlled oscillations commence. This circuit will be recognized as of the electron-coupled family (accorded detailed description in preceding articles of this series), which still further tends to insure the independent oscillating action of the crystal circuit. One of the many advantages of this arrangement is the fact that it will operate efficiently with low voltages. In fact, it is not necessary to exceed the voltage rating of the type –24 tube—a truly unusual condition in an experimental circuit.

Referring to the complete schematic diagram, Figure 2, it will be observed that the wiring of the buffer stage and final amplifier follows standard practice and is self-explanatory. The use of high-mu tubes is desirable, since difficulty is generally experienced in obtaining sufficient r.f. excitation to insure efficient operation of a low-mu tube, such as the type –45. The type –47 pentodes are admirably suited for this type of work. They are exceptionally easy to excite and deliver a satisfactory output with a reasonably low-impedance plate load. In operating these tubes it is important to keep the accelerator grid potential below 200 volts, or excessive heating is almost certain to ensue. The plate voltage may be as high as 400 with apparently no ill effects.

The circuit in Figure 2 may be effectively modulated by a Class B amplifier, such as that shown in Figure 3. The connections between the modulator and power amplifier are evident.

The inductor in the crystal circuit consists of 5 turns of No. 14 bare wire, wound on a 1-inch-diameter form and spaced about ¼ inch. The position of the tap should be determined experimentally, and the optimum will be found between the first and second turn from the low-potential terminal. The circuit should "just oscillate" when detuned from the crystal frequency. The tuning condenser has a maximum capacity of 18 mmfd. The complete crystal unit is shown in photograph, Figure 4.

Data on Parts Used

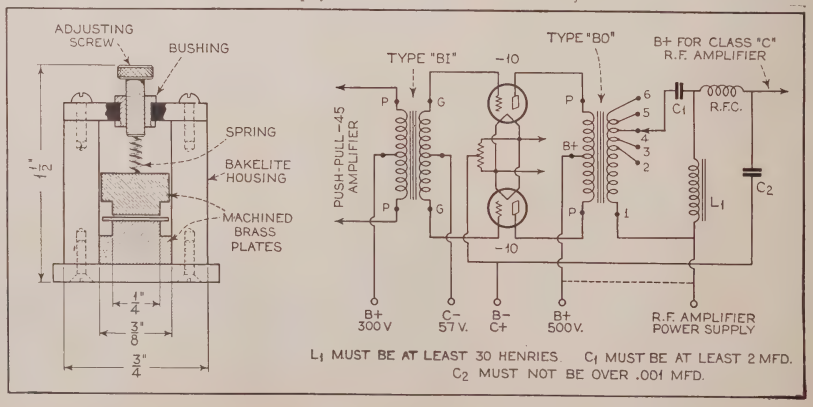
The center-tapped inductors in the buffer and amplifier circuits are wound with 2 turns of ¼-inch copper tubing, 2 inches in diameter. These coils are tuned by C2, C3 and C4, National double stator condensers with 100 mmfd. capacity per section. The radio-frequency choke coils are the special ultra-short-wave, type 100, of the same make. The neutralizing condensers, N, have a maximum capacity of 5 mmfd. Voltages and other values are indicated on the diagrams, Figures 1, 2 and 3. It is essential, of course, that low-loss ultra-short-wave parts be consistently employed in all radio-frequency portions of the circuit.

The crystal holder is shown in Figure 5, which drawing, in conjunction with the rear-view photographs, gives an adequate idea of the construction of this unit. Considerable care must be observed in grinding the plates, which must be flat *within a few wavelengths of light.*

It will be well to emphasize a few general constructional precautions. The layout of the transmitter must be such as to minimize the length of all r.f. leads. The skyscraper construction suggested in the photographs of the experimental transmitter, Figures 6 and 7, is recommended.

THE CRYSTAL HOLDER AND THE MODULATOR CIRCUITS

Figure 5, at left, shows the mechanical constructional data for the crystal holder given with approximate dimensions of the parts. Figure 3, at right, indicates the proper circuit for the class B amplifier—modulator used in this outfit



Any leads carrying r.f., such as excitation leads between stages, must be straight, since a wire, even when only 5 inches long, will offer considerable impedance at 56 megacycles when it is curved or bent. All wiring should be rigid and supported or dampened in such a manner that it will not vibrate. The circuit may be severely detuned, or neutralizing rendered ineffective, by a small displacement of a plate or grid lead.

Perhaps one of the most difficult things to obtain is a sufficiently high impedance in the various tank circuits. Here low-loss and low-capacity technique is of especial importance. The various tank circuits should be characterized by a high L/C ratio.

In experimenting with crystals and holders, considerable time and trouble will be saved by connecting the crystal holder to a simple oscillating detector operating in the desired band. It is only necessary to connect one side of the holder to the grid of the tube. As the oscillator frequency passes the resonance point of the crystal, a distinct click will be heard in the output circuit. An imperfect crystal, or a holder that is improperly ground, will usually result in a series of clicks of varying intensities. Before the crystal and holder can be made to function properly in the transmitter, it is necessary that they be further polished or adjusted until only one loud click is present. Two or three weak clicks on either side of the definite response does not indicate serious trouble, as the crystal will oscillate at the frequency of the loud click. Jarring the crystal and holder slightly will often change the intensity and number of the clicks, this condition being indicative of poor construction in the holder.

While the general procedure in neutralizing the buffer and amplifier is the same as with similar systems operating on longer wavelengths, it will be found that the adjustment is very much more critical. This of course is due to the low impedance which even a very small capacity offers to ultra-high-frequency oscillations. In other words, unless the neutralizers are adjusted with precise care, coupling between the successive tank circuits may be bothersome. While the circuit as a whole may not go into oscillation, interlocking of controls will make the proper alignment of the different circuits next to impossible. It will be found advisable to connect the grid sides of the neutralizing condensers to the excitation taps, rather than directly to the grids of the tubes. This is probably another way of saying that the paths of the neutralizing circuits and of the tube capacity circuits should be equal.

No trouble was experienced in tuning the various circuits when properly neutralized. Detuning caused by changes in the circuit constants, as the tubes cool or heat with load variations, is negligible.

In order to minimize harmonic distortion, the Class B plate supply should have a voltage regulation of 10% or less, and the C bias should be constant. The output transformer secondary should not be used to carry the r.f. amplifier plate current if best tone quality is desired. If, however, some distortion can be tolerated, the secondary can be used for this purpose, with the consequent elimination of the coupling condenser and choke.

It is not advisable to operate the Class B stage without load, as extremely high voltages may be built up in the output circuit, with the possibility of breaking down the coupling or by-pass condensers.

As a general rule, the use of type –10 tubes, having oxide-coated ribbon filaments, is not recommended, as the characteristics are usually different from the standard type for which the transformers are designed.

Figure 8 shows the 56 mc. tourmaline-crystal-controlled transmitter in the National Company laboratory being operated, in conjunction with the Class B amplifier-modulator, by Lloyd Greene, radio editor of the Boston *Globe*. Reception is on the ultra-short-wave superheterodyne, previously described.

This combination results in an effective and practical ultra-high-frequency installation, as well as an excellent nucleus for further experimental work. It is probable that additional progress can be made in the design of ultra-high-frequency inductors, and the author recommends the attention of experimenters to the possibilities of different wire sizes and form factors. It is still an open question whether or not a push-pull circuit is preferable to the single-sided arrangements. In the transmitter shown, no shielding was required. However, with the possible attainment of higher efficiencies, it is probable that the individual stages will require complete isolation.

Also, the limit of the tourmaline crystal for direct oscillation stabilization is considerably above 56 megacycles, and the attention of the pioneer is directed to the duplication or even betterment of satisfactorily stable 1.2-meter transmission which has been accomplished with this remarkable crystal.

Since many experimenters, when they wish to construct multi-stage ultra high frequency transmitters, may encounter difficulty in obtaining satisfactory tourmaline crystals, a word as to the possibilities of the self-excited master oscillator might be helpful.

The circuit is essentially the same as that shown in Fig. 2, the only difference being that the crystal and holder is replaced by a .0001 fixed grid condenser. The cathode tap should be approximately one-third of the way up the coil toward the grid from ground, instead of the one or two turns required by the crystal. The position of the tap must, of course, be determined by experiment and is indicated by a minimum reading of the oscillator plate milliammeter.

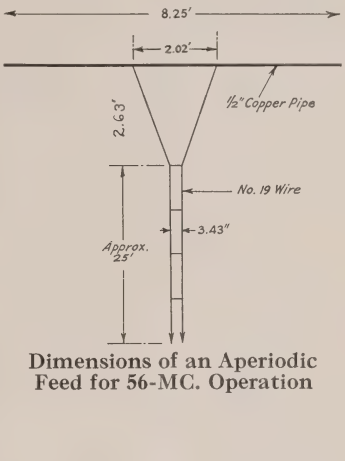
The operation of the circuit as a whole is quite similar to the crystal controlled outfit and requires but little comment.

The electron coupled oscillator circuit has been found, however, to be the only practicable one to use under conditions where voltage variations are apt to be encountered, and such variations are almost sure to be present when using the Class "B" modulator circuit described.

The same care must be exercised in neutralizing the buffer and final amplifier circuits, and it is quite possible that if the type of construction is different from that shown in the photograph, additional shielding will be necessary in order to avoid interlocking of controls. Interlocking is, of course, particularly objectionable when using the self-excited oscillator since it results in a change of frequency.

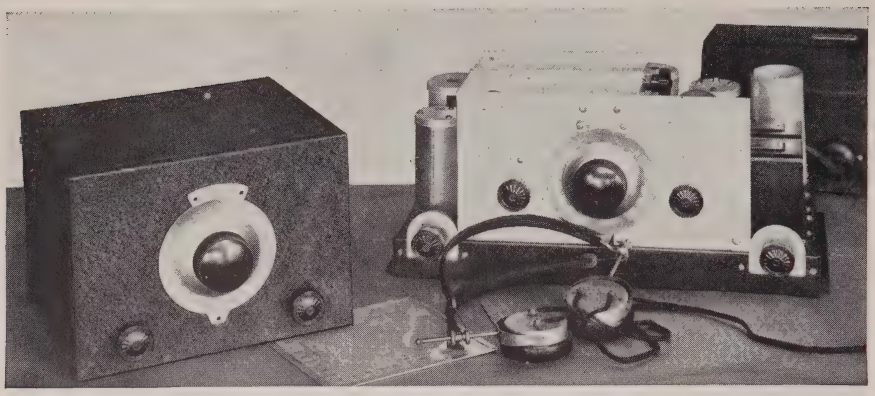
The Doublet Antenna at 5 Meters

The antenna system shown in the sketch below is especially desirable for 5-meter work since the feeders are untuned and may, therefore, be any length whatsoever.



Dimensions of an Aperiodic Feed for 56-MC. Operation

WRITE for our complete catalog of short wave parts and equipment. The National Company Short Wave Headquarters are at your service. Do not hesitate to write us in reference to the adaptability of our products to your personal short wave problems.



ACCURATE FREQUENCY CALIBRATION

Figure 3. Calibrating the ultra-short-wave super described in RADIO NEWS *for August. The vernier movement on the dial facilitates accurate checking and calibration*

HOW THE AMATEUR CAN MAKE ACCURATE

5 Meter Measurements

By **James Millen***

SINCE the first strict enforcement of the 200-meter limitation, the problem of the amateur has been the dual one of designing transmission and receiving equipment effective within the allocations assigned him, and the perfection of measuring instruments which would enable him to tune accurately within legal bands. Off-frequency transmitters have been the initial characteristic of each successive drop in wavelength, the situation becoming more and more erratic as new or lower wavelengths were opened up. Receivers were roughly calibrated against distant transmitters, presumably operating within lawful limits, to be used themselves as standards by other operators requesting "QRH?". Hardly a precise system of wavelength determination but which, in the long run, with many stations using accurate wavemeters or checking their receivers against crystal-controlled standard frequency transmitters, resulted in a natural gravitation, throughout the country, toward the centers of the 80, 40 and 20-meter bands.

This system, however, will not work on the ultra-high frequencies, due to the limited range of such transmitters. It is a case of follow the leader, with no opportunity for double checking on distant stations. The net result is that while all 5-meter transmitters operating within intercommunicating distances are tuned to approximately the same frequency, this frequency is not necessarily within the legal limits and rarely if ever coincides with the "5-meter band" employed by distant groups of intercommunicating amateurs!

The Lecher Wire as a Standard

It is probable that inexpert use of the Lecher wire system as a standard is responsible for many primary discrepancies. While this system is capable of precise measurement, when carefully employed under rigid laboratory conditions and the results interpreted by trained engineers with due consideration of correction factors, its utility for amateur purposes is as about as rough as the technique with which it is generally handled. Inaccuracies as high as ten percent have often been noted, which, at 5 meters, is equivalent to about 10 inches along the wire. The seriousness of such a discrepancy is immediately understood when it is pointed out that a linear error of 6 inches will definitely place the frequency outside the amateur 56-megacycle band.

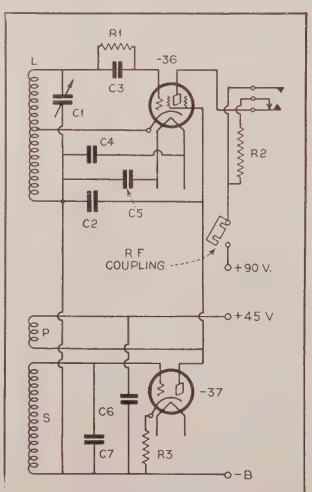
Frequency Meters

It is also logical to consider the possibilities of the conventional resonance indicators—the wave or frequency meters operating either on beat-note or absorption principles.

Frequency meters designed for use on the amateur 20 and 40-meter bands can be used for the accurate calibration of the 56-megacycle transmitter and receiver, due to the fact that the 5-meter band is in harmonic relationship to the lower frequency allocations. (It will be preferable, of course, to employ 20-meter oscillations in making such calibrations, due to the difficulty in discriminating among the 7th, 8th and 9th harmonics of a 40-meter fundamental.)

WIRING DIAGRAM

Figure 1. The circuit of the ultra-high-frequency meter which may be used in the direct calibration of an ultra-short-wave transmitter or receiver



It is assumed that the experimenter possess a transmitter and receiver which he desires to spot somewhere within the 5-meter amateur band. To do this, the following 20-meter equipment may be employed:

1. A transmitter, preferably crystal controlled. If it is not crystal controlled, some means must be provided for determining that it is oscillating at a frequency between 14 and 15 megacycles, the fourth harmonic of which will lie between 56 and .60 megacycles.
2. A powerful local 20-meter transmitter complying with the requirements outlined above.
3. A calibrated 14,000 kc. frequency meter (oscillator) capable of generating fairly strong harmonics.
4. A calibrated 20-meter receiver, or an uncalibrated receiver which can be checked and set by a frequency meter.

The receiver employed should be of the superheterodyne type previously described. This receiver is equipped for

* The National Company.

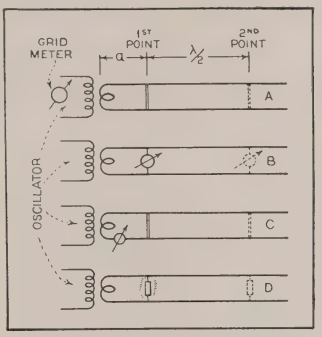
beat-note reception, greatly facilitating the location of the fourth harmonic. If a super-regenerator is used it will be necessary to locate the fourth harmonic by beating with the transmitter (rather a tedious job), removing the suppressor frequency tube for the final precise zero beat.

The general method is obvious and the same for the four sources of 20-meter fourth harmonics. No difficulty should be experienced in locating the fourth harmonic from the transmitter located a few feet from the receiver. The beat-frequency oscillator on the super should now be turned off, the 5-meter transmitter placed in operation and tuned to zero beat with the 20-meter fourth harmonic.

The harmonic from the 20-meter local transmitter is utilized in the same way, and, providing the signal is reasonably strong, little difficulty should be experienced in picking it up. The procedure is exactly the same when employing the 14,000 kc. frequency meter. Several of the dynatron and electron-coupled designs are abundant in harmonics, providing probably the most direct system for calibration as well as "spotting."

The method varies somewhat when employing an oscillating 20-meter receiver. The regeneration control should be pushed up until just below the squealing point, at which adjustment the circuit is probably giving copious vent to harmonics. The 5-meter transmitter is then carefully tuned until a beat-note in the 20-meter receiver is brought down to zero. This beat-note will be caused by the fundamental of the transmitter beating with the fourth harmonic in the receiver circuit.

If any doubt exists concerning the identity of a harmonic, the fourth harmonic can always be checked against the fifth harmonic of a lower frequency. For instance, the fourth harmonic of 14,000 kc. (56,000 kc.) is also the fifth harmonic of 11,200 kc. In other words, if a harmonic is discovered at a certain point on the dial of the ultra-short-wave receiver, when the 20-meter-band oscillator is tuned either to 14,000 kc. or 11,200 kc., the receiver is tuned to 56 megacycles.



LECHER WIRE MEASUREMENTS

Figure 4. Showing several Lecher wire systems which can be used in calibrating ultra-short-wave apparatus. Distance "a" for a given frequency will vary with the system employed. These calibrations are corrected for error by any single "spot" determination of frequency

The Ultra-High-Frequency Meter

While the direct spotting of a point in the 56 mc. band is a simple and practical method of eliminating the possibility of off-frequency operation, the more scientific procedure is to design and calibrate a special ultra-high-frequency meter against which standard the transmitter and receiver may be checked and calibrated in turn. A suitable circuit is shown in Figure 1, while the photographs, Figures 2 and 3, provide general constructional details.

The frequency meter is in the form of a modulated oscillator, in which provision has been made for connecting into the oscillating circuit either telephone receivers (for direct calibration of the transmitter) or an output circuit (for direct calibration of the receiver). In either case the load circuit is electron-coupled to the oscillator and imposes no variation in the calibration of the frequency meter. Stripped to its essentials—with the modulating circuit removed and an output coil permanently substituted for the telephone jack—the design and construction can be simplified somewhat. However, in this more elementary form, the transmitter could be calibrated or checked only in conjunction with the receiver; and receiver calibration is complicated by the lack of a modulated signal.

Referring to Figure 1, coil L is wound with 2½ turns of number 14 wire on an R-39 form having a diameter of 1 inch. The tap is approximately one-third the way from the low-potential end. Coils P and S are respectively the primary and secondary of an audio-frequency transformer with the core removed.

Condenser C1 is the National ultra-short-wave type and has a capacity of 12 mmfd; C2 and C3, .0001 mfd.; C4 and C5, .01 mfd.; C6, .1 mfd., and C7 varies from .01 to .1 mfd., depending on the constants of the transformer coils and modulation note desired.

R1 is a grid leak having a value of 5 megohms, while R2 has a d.c. resistance equal to that of the phones.

The potentials and tubes used are indicated on the diagram.

Calibration can be most readily secured from a lower frequency source by means of a 20-meter-band receiver checked against an accurate 14-megacycle frequency meter. The output of the meter is coupled to the input of the receiver by means of a small coil—five turns of wire on a 1½-inch form—connected to the "r.f. coupling" posts. Coupling should be just close enough to insure satisfactory pick-up. Detector regeneration is turned up so as to secure an adequate supply of harmonics and the frequency meter adjusted for zero beat with the fourth harmonic of the receiver. (The headphones are, of course, plugged into the 20-meter set.)

Any of the other methods outlined above for the calibration or spotting of the 56-megacycle transmitter can be used for the same purpose on the frequency meter. The frequency meter is coupled to the receiver in the manner described in the preceding paragraph.

Where complete calibration is not feasible due to lack of calibration in the 14 mc. band, recourse can be made to the Lecher wire system, providing one definite frequency can be spotted accurately.

Calibrating by Lecher Wires

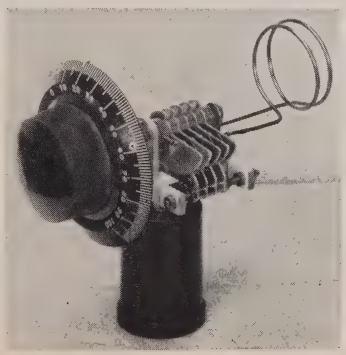
While, as we have pointed out, direct calibration by means of Lecher wires is not to be depended upon, for more than a rough determination of wavelength, the percentage error remains practically constant over the restricted frequency range encompassed by any single band. Therefore, if one spot on the dial can be accurately associated with a certain frequency, by any of the methods previously considered, the error of the Lecher wire measurements can be established and calibration curve consistently corrected.

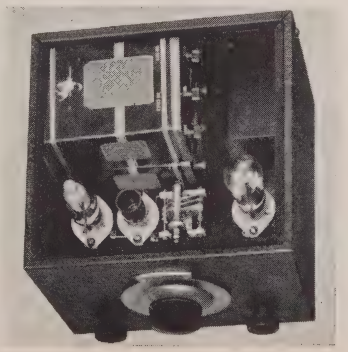
The system of Lecher wire measurement is familiar to most experimenters. It consists, roughly, in extending from the source of oscillations a pair of wires at least one wavelength long and measuring on them the half-wavelength distance between adjacent maxima or minima of current or voltage in the standing waves.

We have found that the most reliable of the simple Lecher wire systems consist of two wires [number 12, (*Continued on page* 29)

TYPES OF FREQUENCY METERS

Figure 2. (Right) Frequency meter with self-contained "B" supply. Figure 5 (Left) Absorption type wavemeter used for rough and reasonably fine checking

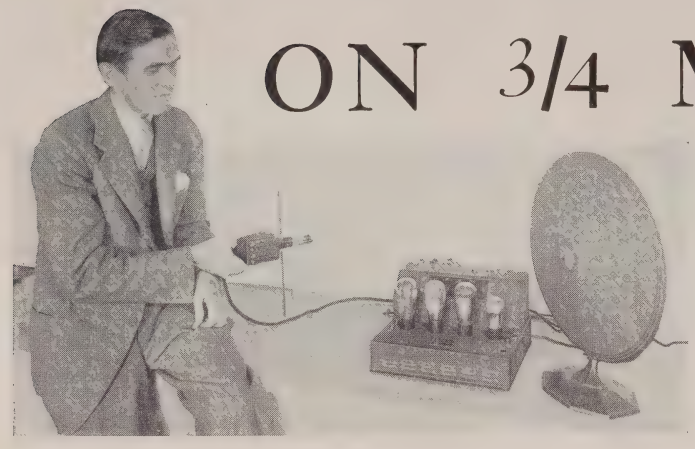




PRACTICAL ON 3/4 METER

Continuing the with constructional details and reflecting antenna wavelengths

By James



AN OPTICAL WAVE RECEIVER SYSTEM

Figure 8. The B.-K. receiver with an audio frequency amplifier and loud-speaker attached for picking up ¾-meter transmissions

THE optical characteristics of ultra-short-wave radio transmission become pronounced only on wavelengths shorter than 5 meters. While it is justifiable to consider any wavelength shorter than 10 meters in the quasi-optical region by virtue of the fact that communication is usually limited to visual distances, the "shadows" are erratic and transmission and reception can be effected by conventional circuits. A wavelength of 5 meters perhaps marks the borderline where circuit differentiation becomes more than mere modification of the usual arrangements, and Barkhausen-Kurz and Gill-Morell hobnob with our familiar friends, Armstrong and Colpitts. But even at 56 megacycles the superheterodyne (RADIO NEWS for August, 1932) is the most efficient receiver yet developed, the super-regenerator is still very effective, while the tourmaline crystal-controlled transmitter is more reliable than the magnetron oscillator.

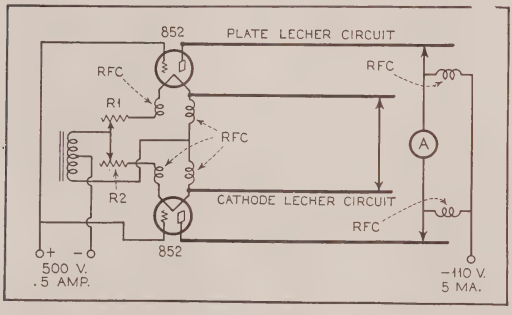
However, still farther down, the picture changes more definitely. The old principles are still recognizable, but apparatus, technique and application are entirely new. While it is by no means as hopeless as Dante's Inferno, we may take liberties with the Florentine poet and declare, "Abandon old ideas, all ye who enter here!"

In the "misty mid-region" of centimeters, the phenomena are markedly quasi-optical, and it is suggested that the experimenter review the first two articles (RADIO NEWS, June and July) in this series, which consider the basic principles and characteristics.

As we shall describe a ¾-meter transmitter and receiver in this article, we shall limit ourselves for the present to 75-centimeter considerations, bearing in mind, however, that the optical phenomena predominate more and more as the wavelength is shortened still further. Communication at 75 centimeters is believed to be limited to between points in a direct line of vision with each other. Even small obstacles, such as trees, cast pronounced "shadows." The wavelength is sufficiently short to permit the use of simple parabolic reflectors, at both transmitting and receiving stations, whereby the signals can be concentrated in accordance with the familiar optical law.

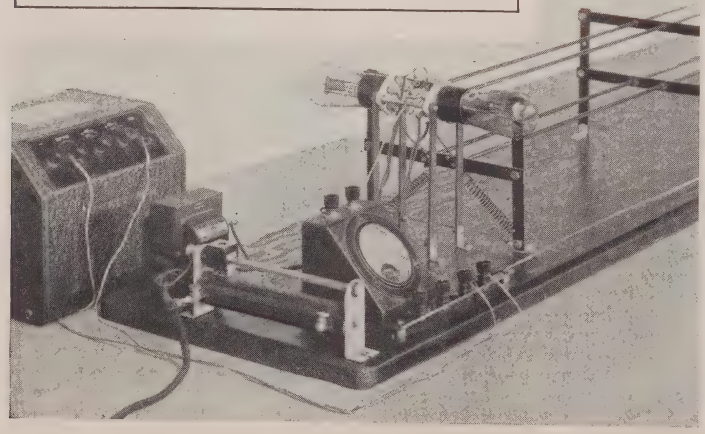
The experimenter who has studied the introductory articles in this series will appreciate that at frequencies above 300 megacycles (300 megacycles equals 300,000,000 cycles per second or a wavelength of 1 meter—just to remind you) the period of the circuit approaches the limitations imposed by the rapidity with which the electrons can circle about in the tube. The velocity of the electron and the geometric spacing of the tube elements, rather than the capacity and inductance of the circuit, may be the deciding factors as to frequency. Such is the case with the Barkhausen-Kurz oscillator, and by varying the accelerating charge on the grid (which, of course, affects the velocity of the electron stream) the wavelength can be controlled over a considerable range, practically independent of the circuit constants. Such a circuit necessarily results in the very unconventional arrangement in which the grid is highly positive and the plate negative.

B-K oscillations can be extended well down in the centimeter region, but are of lesser value for transmitting purposes



CONSTRUCTION DATA

Figure 1, at left, shows circuit diagram of a Kozanowski oscillator. Figure 3, below, experimental Kozanowski oscillator for type –27 tubes



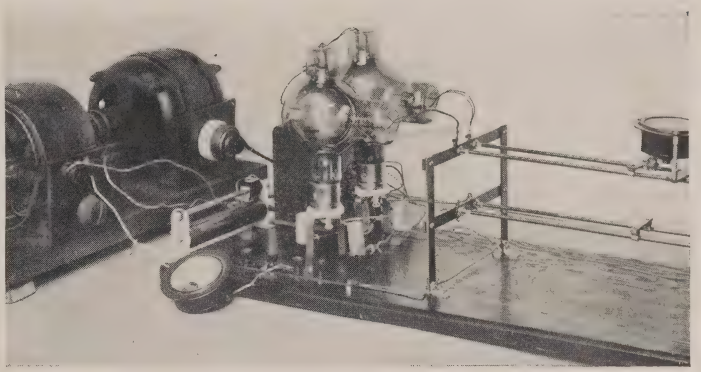
* The National Co.

WORKING DATA

TRANSMISSION

ultra-short-wave series on transmitters, receivers systems for operation on below one meter

Millen*



FINAL EXPERIMENTAL SET-UP FOR 852 TUBES

Figure 2. This transmitter is capable of generating five to six watts of 75 centimeter radiation and is tuned by Lecher wire antennas

below 1 meter, due to low output and lack of stability—the frequency often swinging as much as several megacycles! The lack of stability, however, suggests that the system has possibilities as a receiver, where signal swinging would merely be evidenced as broad tuning. Barkhausen-Kurz oscillators are considered in detail in the June and July articles to which reference has already been made.

It was in an effort to improve the output of the B-K system that Kozanowski developed his oscillator, which departs even farther from the familiar way of things by tuning the plate and filament circuits rather than the plate and grid circuits. Kozanowski's investigation into a modified Barkhausen-Kurz oscillator indicated that the oscillations were the result of the space-charge fluctuating geometrically (not in potential) about the grid. In other words, the vibratory phenomena pivots about the grid, the filament and plate being the high-potential sides of the oscillating system. Such a theory would suggest an improved output with the filament and plate circuits balanced or tuned—an assumption thoroughly justified by further experimentation.

The Kozanowski oscillator circuit used by the author in ¾-meter experiments is shown in Figure 1, while the photograph, Figure 2, provides a clear idea of the mechanical arrangement. The plate and filament circuits are tuned by individual Lecher wire systems. The wavelength at which the oscillator functions is determined by the length of the plate Lecher system. It must not be assumed, however, that we have here merely a modified oscillator operating on the tuned-plate principle. It is, of course, a bona fide electronic oscillator, as is evident by the reversed potentials on grid and plate, and the fact that the wavelength is almost exactly equal to the length of the plate Lecher system as measured from the plates of the tubes to the terminating ammeter, quite independently of concommitant inductance and capacity.

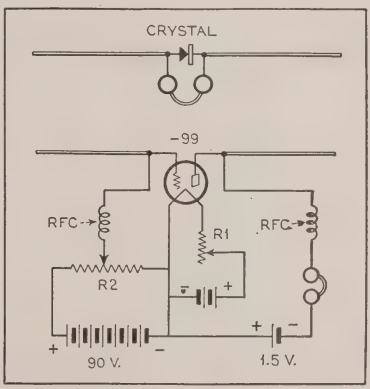
From considerations outlined above, it is evident that the power output can be controlled by varying the length of the cathode Lecher system, which has practically no effect on frequency. The oscillating power generated by the Kozanowski circuit is considerably greater than that obtained by a B-K oscillator. The best output reported from Barkhausen-Kurz circuits at 75 centimeters has been a fraction of a watt, whereas the circuit in Figure 1, employing the tubes and potentials indicated, can be pushed to well over 5 watts, at this wavelength, with good stability.

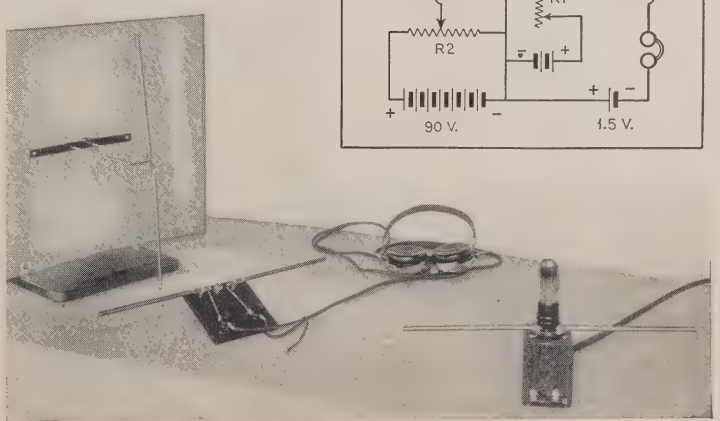
The 852 type tube is admirably suited to oscillations of this character. Original experiments carried on with the type –27 tubes (Figure 3) showed that our old ultra-high-frequency standby will not provide satisfactory results in this circuit. While oscillations were present, they did not exhibit the proper characteristics. The plate circuit showed practically no frequency control, and the length of the cathode circuit had a negligible effect on the power output. Oscillations ceased when a plate potential of more than a few volts negative was applied. The circuit was apparently functioning as a Barkhausen-Kurz oscillator, and increasing the grid potential up to the point where the grid ran white-hot did not improve matters.

However, upon substitution of the type 852 tubes, as shown in Figure 2, the circuit settled down and operated strictly in accordance with Hoyle—or, rather, Kozanowski. It was necessary to apply at least 200 volts to the grids before the power output became sufficiently great to light a small flashlight bulb.

RECEIVER CIRCUITS

Figure 4, below, shows resonating crystal and tube receivers. Figures 6 and 7, at right, show the crystal receiver and the simple tube receiver, respectively





With the accelerating potential increased to 500 volts it was possible to obtain a power output between 5 and 6 watts. With this voltage applied to the grids, the filament circuit of each tube should be adjusted, by means of R1 and R2, to limit the grid current to about 250 milliamperes per tube. Careful matching of tubes is unnecessary when provision is made for this adjustment. The negative plate potential should be about 110 volts. The plate current varies from 5 to 6 milliamperes, while the oscillatory current in the plate Lecher circuit is about 2.5 amperes at no load.

Needless to say, the grids of the tubes become extremely hot, but since the filament emission is not excessive, the life of the tubes should not be materially shortened.

It will be found that the negative plate voltage, for best output, is rather critical, and that as the plate voltage is increased from the optimum value, the power output decreases proportionately. This condition suggests that the circuit is readily amenable to modulation, which can be effected most economically due to the fact that the power required is only about 6 watts. The usual straight-line considerations are involved, and the steady plate voltage should be set midway between the optimum value and the point at which oscillations cease.

Construction Details

The constructional details are well illustrated in the photographs. The Lecher wires are made of ¼-inch copper rods, supported rigidly by isolantite and R-39 insulating material. The filament choke coils consist of 15 turns of No. 12 double-cotton-covered wire, wound with a ¾-inch diameter. The plate-circuit chokes can be the same, or, if more convenient, of 20 turns of No. 18 enameled wire, with a diameter of ½ inch, and stretched, spring fashion, until they are two inches long.

Once the oscillator is functioning satisfactorily, there remains the problem of providing a suitable antenna system and of coupling it to the plate Lecher circuit. The most interesting features of ¾-meter experimentation are, perhaps, the miniature radiating systems and the sharp directional effects which they can be made to produce.

The simplest antenna consists of a 15-inch piece of copper rod (Lecher wire material), one end of which is clipped to the plate Lecher circuit. Any desired amount of coupling can be obtained by clipping the rod antenna at different points along the plate circuit. While a simple radiator of this description will work fairly well, it is definitely inferior in efficiency to the reflector systems shown in Figures 4 and 5. The antenna is a current-fed doublet and is located in the focus of a semi-parabolic reflector. The feeder system is one wavelength long and is inductively coupled to the plate Lecher circuit. The mechanical degree of coupling can be ascertained by reference to Figure 5. A reflector of this type will concentrate the radiation in a fairly sharp beam which will be many times more powerful than that emanating from an open antenna system.

Antennas and Feeders

A later version of the reflector, which gave improved results, was similar to the above described arrangement with the exception that the feeder system, three-quarters of a wavelength long, was clipped directly to the Lecher system. It is probable that this voltage-feed method is to be preferred, as it is rather difficult to obtain satisfactory inductive coupling to the Lecher circuit because of its shape.

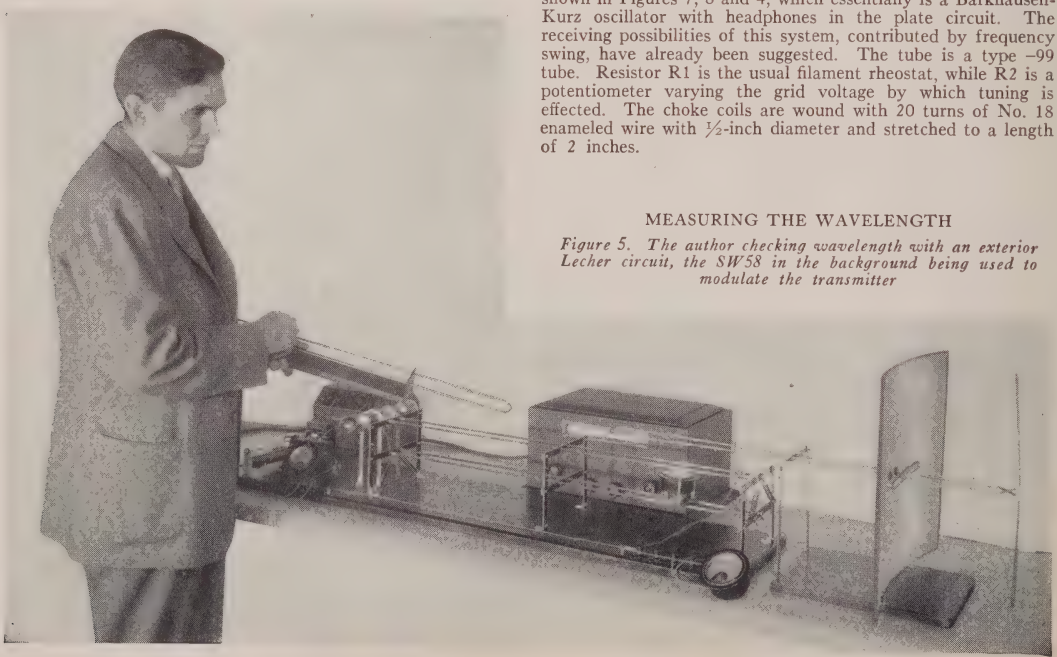
The wavelength of the radiated wave may be measured on an independent Lecher system if desired, as shown in Figure 5. The slide may be either a sensitive microammeter, a small flashlight bulb (when relatively high powers are being radiated) or a simple short-circuiting bar, resonance being indicated in the latter case by a variation in the plate Lecher oscillatory current. However, checking in this way is hardly essential, because, as already explained, the radiated wavelength is equal (with negligible error) to the measured distance between where the Lecher wires connect to the plates (within the tubes) and the terminating bridge.

Before extensive experiments can be carried out, it is essential to have some form of receiver. The simplest is the crystal unit diagrammed in Figure 6 and photographed in Figure 4. This consists of an iron pyrite crystal detector connected between two 7-inch lengths of rod—the overall length approximating 15 inches or ½ wavelength at 75 centimeters. The headphones are connected directly across the detector.

This arrangement, while insensitive, is extremely useful in checking modulation, the directional effects of different radiators, etc., due to the fact that its low sensitivity permits its use in the immediate field of the transmitter. An interesting phenomenon will be observed in a preliminary search with this receiver. When the antenna rods of the receiver are parallel with those of the transmitter, the received signal will be strong; at right angles the signal cannot be heard—demonstrating the sharply polarized nature of the radiated wave.

Receiver Equipment

A receiver more practical for communication purposes is shown in Figures 7, 8 and 4, which essentially is a Barkhausen-Kurz oscillator with headphones in the plate circuit. The receiving possibilities of this system, contributed by frequency swing, have already been suggested. The tube is a type –99 tube. Resistor R1 is the usual filament rheostat, while R2 is a potentiometer varying the grid voltage by which tuning is effected. The choke coils are wound with 20 turns of No. 18 enameled wire with ½-inch diameter and stretched to a length of 2 inches.



MEASURING THE WAVELENGTH

Figure 5. The author checking wavelength with an exterior Lecher circuit, the SW58 in the background being used to modulate the transmitter

The antenna system has the same overall dimension as that employed in the crystal receiver.

The B-K receiver can be used either in an oscillating or stable state, depending on whether cw or a modulated signal is being received. Oscillations are suppressed by increasing the plate voltage slightly, in which condition it functions as a relaxation period tuner — a signal being favored, or tuned, the frequency of which corresponds to the relaxation period of the electron stream as governed by the grid potential. Oscillations are actually induced by the incoming wave — which, of course, is also favored by the dimensions of the pick-up system.

The output of this receiver can be readily amplified in conventional circuits — a combination receiver and amplifier being shown in Figure 8. With such a receiver, the transmitter described can be heard with good volume for several hundred feet. Under favorable conditions, communication has been established over a distance of several miles with this apparatus. Such results, however, are not easy to duplicate, and the experimenter may be gratified if he can pick up a good signal ¼-mile from the transmitter.

It is obvious that plenty of room exists for further development of the receiver. The addition of super-regeneration should result in greatly improved sensitivity. While the advantages accruing from the use of this system will not be so great as in the 5-meter band, experimentation along this line will be amply justified.

5-Meter Measurements

(*Continued from page* 25)

bare], each 25 feet long, separated from 6 to 8 inches, and coupled to the oscillator (the 56-megacycle transmitter) by means of about two turns of wire, 2 inches in diameter, at the closed end. The easiest way of making such a system is to take 51 feet of wire, wind the two turns in the middle, and stretch the wires in a convenient direction. The proximity of walls apparently has little effect on the accuracy of the measurements, and stand-off insulators can be used. The required length of the wires can be shortened somewhat by shunting a small condenser — 5 to 10 mmfd. — across the two turns. This tends to bring the first point of measurement closer to the input, but does not change the distance between the first and second points, which is what we are after. (Do not measure between the input end and the first point.)

There are four possible Lecher wire methods recommended to the amateur in varying degrees of convenience, and which are shown in Figure 4. The variations are in the nature of the movable bridge. In A, the bridge is a length of heavy copper wire which short-circuits the Lecher wires. It is moved along the wires until points 1 and 2 are discovered which give the maximum dip on a grid meter in the oscillator. The wavelength is twice the distance between points 1 and 2.

In system B, the bridge consists of a microammeter which is moved along the wire, indicating maximum current at current anti-nodes — again spaced one-half wavelength apart.

In C, the bridge is again a short-circuiting wire and maximum current readings are taken from the microammeter, in series with the two-turn pick-up coil.

In system D a sensitive neon lamp is moved along the wires to locate two voltage maxima one-half wavelength apart.

The Lecher wire system should always be coupled as loosely as possible to the transmitter, while still allowing sufficient coupling for the accurate determination of the nodal or anti-nodal points.

Regardless of which system is used, the general procedure is the same. The signal is picked up on the frequency meter, the dial reading and wavelength noted, and the latter converted into frequency if desired. Additional measurements are made with different settings on the transmitter, Lecher wire and frequency meter, until sufficient points are secured to plot a curve, which is corrected, as before explained, by reference to an accurate "spot" frequency.

Absorption Meters

The absorption type meter can be used for quick and approximate frequency determinations. In general, the same sources of error which make this type of measurement undesirable for lower frequencies are much more insidious in ultra-high-frequency work. A large error will result if, for instance, the experimenter attempts to absorb enough energy to light a series lamp from a low-power, 5-meter oscillator. If, however, the wavemeter is used in conjunction with a highly sensitive thermo-galvanometer as an indicating device, it will give fair results on transmitter measurements. Similar reliability can be placed on loosely coupled absorption measurements when a grid meter in the transmitter circuit is used for resonance indication.

Photograph, Figure 5, provides constructional data on a simple absorption type meter. The coil is wound with two turns of number 12 wire with a diameter of about 1½ inches, spaced ½ inch. The condenser has a maximum capacity of 12 mmfd. The wavemeter is mounted on an R-39 coil form which is used as a convenient handle.

The absorption type meter is calibrated in exactly the same manner as described for the oscillating frequency meter.

56 Megacycle Amateur Band

(*Continued from page* 10)

Installation

To install the converter, it is only necessary to connect suitable power supply equipment, connect the output post to the antenna post of the broadcast receiver and connect the ground post of the converter to the ground post of the receiver. These two wires should be twisted loosely together or may be run closely parallel to each other. Ordinarily, shielding these leads is not required. The converter should not be placed more than 6' from the receiver and it is usually much more convenient from the operating standpoint to place the two units side by side.

The two coils accompanying the converter, while similar in appearance, have definitely different electrical characteristics. The coil having the red mark on the base should be placed in the detector coil socket (left hand compartment) while the coil marked with black is for use in the oscillator circuit (right hand compartment). The coils must be placed firmly down in their sockets or trouble will be experienced in obtaining correct ganging and maintaining calibration. It will be noticed that the connecting leads between the ends of the coils and the pins in the coil form are bent. These leads must not be straightened or altered in any way since the coils are individually calibrated by carefully adjusting the leads in the laboratory. When the converter is properly aligned, the range from 56–60 megacycles will cover from approximately 135–55 on the dial. The calibration of individual sets may vary appreciably, however.

Operation, Alignment, Etc.

After the converter has been properly connected, the broadcast receiver should be tuned to approximately 1550 K.C. and the volume control fully advanced. From left to right the converter controls are detector trimmer condenser, tuning control and detector regeneration control. The oscillator padding condenser will be found at the top of the oscillator (right hand) compartment.

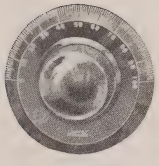
It is first necessary to set this padding condenser to properly align the oscillator and detector circuits. The detector trimmer condenser should be set at approximately half capacity and the tuning dial at about 100. No signal is necessary during this procedure other than the usual back ground hiss from static, tubes, etc. Starting with the regeneration control (right hand knob) fully advanced, rotate the padding condenser back and forth over the entire range, meanwhile, slowly reducing the regeneration. At a certain setting of the regeneration it will be found that as the padding condenser is rotated, the back ground noise will sharply increase at two points. At these points the oscillator is aligned with the detector, the lower capacity setting of the padding condenser being the correct adjustment since the oscillator is designed to work on the high frequency side of the detector. In other words, while there are two points where the oscillator and detector may be aligned (when the oscillator is tuned either above or below the detector by the amount of the intermediate frequency) the correct setting of the oscillator is equal to the detector frequency plus the intermediate frequency. Under certain conditions, where the capacity of the tubes employed vary somewhat from normal, the padding condenser may be almost at its minimum capacity. It will now be found that by rotating the detector trimmer control the back ground noise will peak at approximately half capacity. Further reducing the regeneration will broaden the peak and reduce its amplitude until finally it will no longer be apparent. Advancing the regeneration, the peak will increase until the point is reached where the detector actually goes into oscillation at which time the converter will be practically inoperative due to detector overload from its own oscillation and due to I.F. overload by the strong beat between detector and oscillator. When actually receiving signals, maximum sensitivity will be obtained with the regeneration control adjusted just below the point at which the detector oscillates. As the tuning dial is varied from one end to the other, it will be necessary to readjust both trimmer and regeneration slightly since the action of both controls vary with frequency. They need not be set with extreme accuracy unless reception of very weak signals is desired.

Two other adjustments may warrant a word of explanation. These are the detector I.F. trap circuit and the I.F. transformer which couples the detector to the output tube. The trap circuit is located in the detector compartment on the extreme left-hand side and consists of a lattice wound coil and a compression type tuning condenser. The I.F. transformer adjustment is located directly in back of the output coupling tube (*227* or *237*). Both these circuits should be adjusted to the intermediate frequency. The trap circuit may best be adjusted after the converter has been put in operation by setting the condenser with a bakelite screw driver at the point which gives maximum back ground noise (such as a vacuum cleaner) so that the detector trimmer and regeneration need not be in their critical positions, since the trap circuit adjustment has some effect upon detector tuning. The intermediate frequency transformer may be tuned very simply in the same way.

Velvet Vernier Dials

Types E and F

Types G and H



Type A

Type N

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COLORADO
Vreeland Radio Corp., 1639 Tremont Street, Denver, Col.

CONNECTICUT
Hatry & Young, Inc., 203 Ann Street, Hartford, Conn.

GEORGIA
Garvin Electric Co., 75 Forsyth Street, N.W., Atlanta, Ga.

ILLINOIS
Chicago Radio App. Co., 415 S. Dearborn Street, Chicago, Ill.
Newark Electric Co., 226 W. Madison Street, Chicago, Ill.
Midwest Radio Mart, 520 So. State St., Chicago, Ill.

INDIANA
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MARYLAND
Radio Electric Service Co., 303 W. Baltimore St., Baltimore, Md.

MASSACHUSETTS
H. Jappe Co., 46 Cornhill, Boston, Mass.
Sager Electric Supply Co., 201 Congress Street, Boston, Mass.
Woodrow Radio Co., 166 Prospect Street, Cambridge, Mass.
T. F. Cushing, 345 Worthington Street, Springfield, Mass.
Tremont Electric Supply Co., Tremont St., Boston, Mass.

MISSOURI
Walter Ashe Radio Co., 1100 Pine Street, St. Louis, Mo.
Burstein Applebee Co., 1408 McGee Street, Kansas City, Mo.
Kansas City Radio Co., 1314 McGee Street, Kansas City, Mo.

MINNESOTA
The Lew Bonn Co., 2484 University Ave., St. Paul, Minn.
Palmer Anderson Co., Route 1, Box 270, Duluth, Minn.

MICHIGAN
Radio Specialties Co., 171 E. Jefferson Ave., Detroit, Mich.

NEBRASKA
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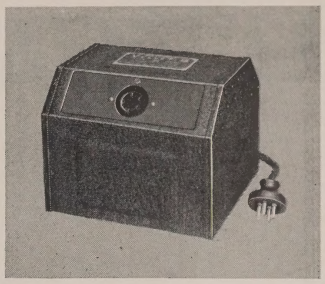
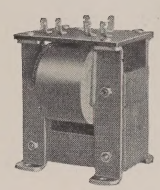
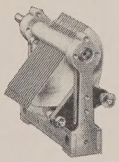


Velvet A-B Power Units. Manufactured Under R.C.A. License

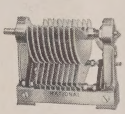


Power Transformer Type U

Velvetone Audio Transformer



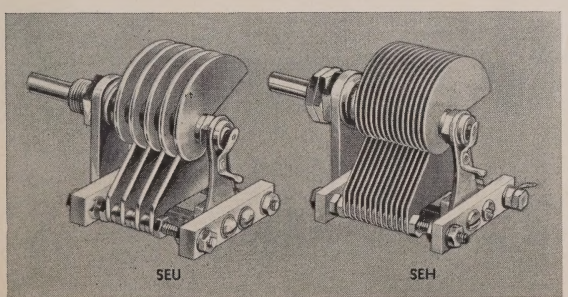
Girder Frame Tuning Condenser



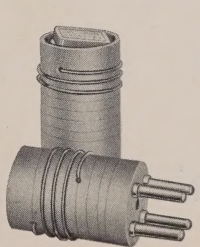
Equicycle Short Wave Condenser

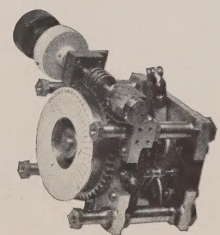
"Grid-Grip"

R. F. Choke



Precision Parts for Efficient Short and Ultra Short Wave Receivers





Laboratory Precision Condenser

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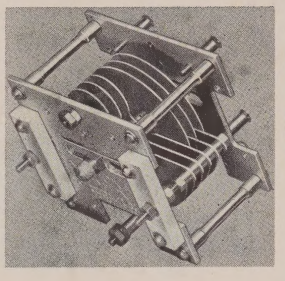
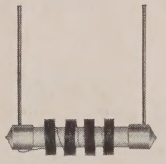


40–75 BAND SPREAD CONDENSER

For use in frequency meters and short-wave band-spread circuits.

Minimum Capacity
40 mmf.

Maximum Capacity
75 mmf.



TYPE NO. 100 R. F. CHOKE

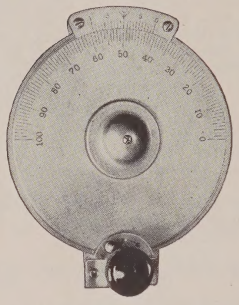
R.F. Chokes have always been a problem in short-wave work. The No. 100 R.F. Choke is designed especially for high frequency receivers.

Extremely low distributed capacity. Consists of four narrow sections, each universal wound, spaced on Isolantite form. Supplied with stiff leads for mounting but fits in grid-leak clips if desired.

Approximate Characteristics:
D.C. Resistance 50 ohms
Distributed Capacity 1 mmf.
Inductance 2½ millihenries
Will carry 125 milliamps without heating

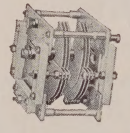
Type BM MIDGET 3" Velvet Vernier Dial

A new 3" size of the well known Type B Velvet Vernier Dial, produced to meet a popular demand for a smaller dial with the V.V. mechanism, for use on small receivers and transmitters. Made with fixed ratio only: Type BMD with dual range 0–100–0 and type BMC 200–0 clockwise.



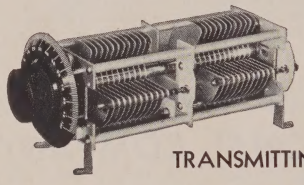
NEW 6" Velvet Vernier DIAL Type NW

An entirely new 6" Velvet Vernier Solid German Silver dial for amateur and laboratory use. Capable of extreme precision. Flush vernier eliminating parallax reads to 1/10 division and may be estimated to 1/20 division. Equipped with 3-point variable ratio, this dial is in a class by itself.



TYPE EMP CONDENSER SPLIT-STATOR

A split-stator condenser for receivers and low power push-pull transmitters. Special low-loss stator-insulators are used. 1200 volt breakdown. Single spaced. Standard size 100 mmf. per section, but can be furnished up to 350 mmf. per section.



Type TMP TRANSMITTING CONDENSERS

A split-stator condenser for medium power push-pull transmitters and "High C" Circuits. Especially suited for 5-meter work where extremely accurate balance between both sides of the tank coil is necessary for best efficiency. Isolantite stator-insulators, polished plates with rounded edges, self-aligning conical bearings, rigid frame construction.

Standard Sizes:
TMP 100 — 100 mmf. per section — 3000 V.
TMP 230 — 230 mmf. per section — 3000 V.
TMP 100A — 100 mmf. per section — 6000 V.

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